AN ECONOMIC STUDY OF PRESTRESSED CONCRETE

GEORGE L. HOFFMAN AND
CHARLES B. HOGAN

AN ECONOMIC STUDY

OF

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George L. Hoffman, LTJG, CEC, USN

and

Charles B. Hogan, LTJG, CEC, USN

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INTRODUCTION

The purpose of this thesis is to compare the cost of prestressed concrete structures with the cost of conventional structures and to determine if, and under what conditions, prestressed concrete compares favorably. This comparison is not all-inclusive because of time limitations. It is a start in a field previously undocumented, and it is hoped by the authors that the investigation will be continued and extended to other designs.

The investigations in this thesis include a comparison of fourteen simple rectangular beams, a small highway bridge, and a larger highway overpass bridge. The fourteen simple beams were chosen as a starting point because they represent an element found in many structures. Since it was impossible to investigate all the conceivable combinations of spans and loads, the fourteen were chosen as common ones encountered in practice. The small highway bridge was selected because of its simplicity and also because it was the first prestressed bridge completed in this country. The highway overpass bridge is a typical example of large bridges being constructed in considerable numbers by the highway departments of most states. The contract for this bridge has been awarded and the bridge will be a part of the New York Thruway.

Prestressed concrete is a relatively new method of bridge and building construction in the United States; however, it has been used to a considerable extent in circular tanks and piping. At the time of this writing, the only completed bridge of major proportion was the Walnut Lane Bridge in Philadelphia. This bridge was also the first project to be started in this country. A smaller bridge in Madison County, Tennessee, was begun after the Walnut Lane Bridge but was completed before it, thereby gaining the distinction of being the first prestressed concrete bridge completed in this country. The cost of the prestressed bridge in Madison County, Tennessee, is compared with a conventional design for the same site in Part II of this thesis.

Prior to its introduction in the United States, prestressed concrete had been used for some time in Europe (1)[1]. The supply of materials, especially steel, has always been critical in Europe, even more so during and after World War II. Since prestressed construction results in an economy of materials, it has been used extensively there (2). The European methods of prestressing entail the placing and stressing of individual wires or small groups of wires at one time. This results in considerable labor, however it is not a controlling factor because Europe has a large supply of cheap labor.

1. Numbers in parentheses refer to Reference numbers.

Prior to the late 1930's the American supply of iron ore was considered relatively inexhaustible. By relatively inexhaustible, it is meant that there was a plentiful supply for the next forty or fifty years, and within that period it was reasonably expected that new techniques would be developed which would make possible the use of impure iron deposits. The steel industry also expected to find new rich deposits during that period. The drain of reserves caused by World War II and the increased peacetime use have depleted the supply to the point that the Lake Superior deposit will be exhausted within the next ten to twelve years. A considerable amount of capital has been invested in research and successful methods have been developed to beneficiate the impure ores. The use of these methods, however, will entail a considerable increase in cost due to the additional processing (3). New deposits have recently been discovered in South America, and it is planned to use these deposits as much as possible in the future, thereby prolonging the life of the Lake Superior ranges. In an emergency, however, an enemy or a change of local government could deny us access to these ores. It is an accepted fact that prestressed concrete results in a considerable saving in steel. This being the case, prestressed concrete construction can and should play an important part in our future.

The supply of concrete itself has not been equal to the demand during the summer and fall months of each year since World War II. Its tremendously increased use in highway pavements has been one of the main causes of this shortage. In addition the heavy demand for cement by the construction industry during this period shows no sign of abatement, and it is anticipated that the shortage will be even more critical during the summer and fall of 1951.

It is the authors' opinion that the development of a very high strength single strand to replace the individual wires, common to European practice, by the John A. Roebling's Sons Co. will result in an economic utilization of labor in this country, despite the high level of wage rates. Although this strand requires a much larger jacking unit, this simplified method is considered a characteristic expression of American ingenuity and implementation.

Before prestressed construction can be economically utilized in this country, it must: 1. be accepted by the designing engineers who are reluctant to adopt radically new designs, and 2. be accepted by the contractors who are naturally hesitant to give realistic bids on the prestressing operation itself, because of their unfamiliarity with the work. The latter results in high bids even though the quantities of material are smaller, and consequently no economy is realized by the builder.

There is a distinct possibility that the material situation may become so critical that the use of prestressed construction may be imperative in order to conserve materials, even though it may not be the most economical in all applications.

PART I

COMPARISON OF SIMPLE RECTANGULAR BEAMS

As is stated in the Introduction, it is impossible to investigate all the conceivable combinations of spans and loads; therefore, fourteen were chosen as common ones encountered in practice. The spans and loads are as follows:

Span	Load	Span	Load
20 feet	200 ppf	40 feet	100 ppf
"	300 "	"	200 "
"	400 "	"	300 "
"	500 "	"	400 "
30 feet	100 "	"	500 "
"	200 "		
"	300 "		
"	400 "		
"	500 "		

The quantities for each beam are 1, 10, 100 and 1000. The comparison will include: 1. quantities of materials, 2. labor cost, 3. material cost, and 4. total cost.

Conventional Design Procedure

In the conventional design the procedure and tables of the Reinforced Concrete Design Handbook were used exclusively. The allowable stresses were taken from ACI Standards - 1949. A depth to breadth ratio of 2 to 1 was used, as this ratio is considered to give the most economical section (4). The results of these design computations are given in Table I, page 19. Since there is no appreciable difference in the

price of concrete in New York City, 3750 psi concrete was used to give a higher allowable diagonal tension stress and therefore eliminate stirrups.

Prestressed Design Procedure

The prestressed design was based on a method developed by Mr. Fred J. Uziel, Staff Engineer, Preload Corporation, N. Y. Since the purpose of this thesis is an economic study, the details of the design procedure are not given. The results of the computations are given in Table II, page 22. For a complete presentation of the method, the reader is referred to Reference 5.

As with the conventional design, a depth to breadth ratio of 2 to 1 was used. In Mr. Uziel's method, a depth must be assumed. To eliminate trial and error in determining the depth in each case, a formula of Magnel's was used (6).

$$\frac{bD^2}{6} \geqslant \frac{M_a}{.775c + c_t}$$

M_a = the moment due to the live load

c = the permissible compressive stress in concrete

c_t = the permissible tensile stress in concrete

b = the breadth

D = the depth

By setting $b = \frac{D}{2}$ the only unknown is D and it can therefore be solved directly.

The symbol "c" shown in the design table is defined in Mr. Uziel's method as the ratio of area of strand hole to the area of the section. The value of c = 2.5% used in the design was chosen because it is a very conservative value. In all cases the actual ratio is much less than 2.5%.

At the time of this writing, no codes for prestressed design had been adopted. Since in prestressed design the entire section is considered to resist flexure, a 5000 psi concrete was used. The allowable stresses based on 5000 psi are tabulated in the design table.

An allowable diagonal tension stress of 3% of f'_c or 150 psi is assumed. In the design table the computation of horizontal shear at the neutral axis, as a measure of diagonal tension, was based on $v = \frac{3V}{2A}$.

v = intensity of horizontal shear in psi

V = total shear due to applied loads and beam wt. in lbs

A = total cross-sectional area in $in.^2$

In all cases v was less than the allowable intensity of unit stress. There are two additional considerations which must be included if an exact solution is to be made for the maximum principal tensile stress. These are the shear force due to the curvature of the strand and the compressive stress in the end of the beam due to the stress in the strand. Since these two factors will reduce the value of the maximum

principal tensile stress below that calculated for v above, the results tabulated are conservative.

The size of the prestressed strand required is determined by the value of "P" in the Prestressed Design Table, page 23. With this value of "P" the cable size is selected from the Strand Physical Properties Table, page 24.

Basic Assumptions

The plant is assumed to be set up expressly for each beam casting job.

One beam will be poured on the job site with one wood form by carpenters and common laborers.

Ten beams will be poured on the job site with two wood forms by carpenters and common laborers.

One hundred beams will be poured on a special site constructed or existing for this purpose with ten steel forms by carpenters, steel workers and common laborers. The forming operation itself will still be done by carpenters even though steel forms are used. The steel worker will place and tie the reinforcing bars in the conventional beams and the prestressing strands in the prestressed beams.

One thousand beams will be handled the same as one hundred except that fifty steel forms will be used.

The wood forms are plywood contact surfaces with 2x4 bracing 16" cc. For one beam the salvage value of the lumber is one-half its initial cost. For the ten beam job two wood forms are used and after five pourings each, the material has no salvage value.

The steel forms are fabricated for assembly and disassembly in lengths of approximately five feet. They are two-piece clamp type with open top. It is estimated that the life of this form is one-thousand pourings. This number of re-uses which is higher than claimed by manufacturers is used because the concrete is to be poured on an oiled concrete floor and not in place in a structure. Thus each pouring absorbs 1/1000 of the total cost of one form.

For the one and ten beam groups the hours of carpenter and common labor per 100 square feet of contact surface (SFCS) for each type of form was based on past estimates of conventional beams and columns in place in reinforced concrete buildings. This was the lowest estimate in hours given in a series of similar structures. Naturally the time required to erect and disassemble a beam in place would be much higher than doing the same work on the ground level with no scaffolding required and where working conditions are much more expedient. Therefore, instead of reducing this time, it is assumed that the extra time above that for the general

erecting, disassembling, and cleaning will be taken up in placing reinforcing bars, operating vibrators, cleaning the floor area, oiling the floor area, etc., and accomplishing other jobs which are not necessarily allowed in conventional work or which are done by other workers.

For the 100 and 1000 beam lots the steel placing would be done by structural iron workers. The amount of carpenter labor has been reduced proportionally to allow for this change. The placing of the forms, etc., is still done by the carpenters, even though the forms are of steel.

In order to be more specific the authors have used the wages for carpenters, structural iron workers, and common laborers in New York City as of January, 1951, as reported in Engineering News Record of January 11, 1951.

The average price of ready mix concrete in New York City in January, 1951, was used. The same price of ready mixed concrete was used for both the conventional and the prestressed beams, because of the high quality of aggregates available in that area. The concrete price is per cubic yard delivered and poured wherever the contractor desires.

Reinforcing bars will be purchased in lots over one ton and will be delivered bent, hooked, and ready for placing in

the beam. The price of the bars is that in January, 1951, as taken from the Engineering News Record of January 11, 1951.

Prestressing strands will be purchased in actual lengths required, ready for placing in the beam. The price is quoted by John A. Roebling's Sons Co. for January, 1951.

The bearing assembly for the prestressed beam consists of a flat plate with a hole just large enough to allow the male thread on the end socket to pass through. A cardboard tube will be placed around the socket and strand and held flush against the inside of the bearing plate by wire ties. The end around the strand will be stuffed with paper to prevent the concrete from running into the tube, thus preventing any contact between the socket and the concrete. The entire length of the strand is wrapped with heavy brown wrapping paper and tied with wire ties. This prevents the concrete from bonding to the strand, allowing the strand to elongate uniformly throughout its entire length during prestressing.

COMPUTATION OF BASIC UNITS AND BASIC UNIT COSTS

I. One and Ten Beams

A. Forms

One and ten beams are formed by plywood forms. It would be impossible to price each plywood form every time, so an average size beam was chosen and a hypothetical form

was made to arrive at a unit price per SFCS. This figure was then applied to all plywood forms. This form is three-sided, the top being left open. It is 5/8" plywood, studded with 2x4's, 16" cc.

1. Lumber Quantity for a Beam 1'w, 2'd, 30'L

   Fir plywood 5/8" thick

   Sides 2(2' x 30') = 120 ft.^{2}

   Bottom (1' x 30') = 30 ft.^{2}

   Total SFCS = 150 ft.^{2}

   2x4 studs 16" cc

   Form braced on four sides

   2(24"d + 4" + 4" lap) = 64"

   2(12"w + 4" + 4" lap) = 40"

   104" per stud

   No. of studs = $\frac{30 \times 12}{16} = 23$

   23 x 104" = 2392" = 199.3' of 2x4's

2. Lumber Prices

   Plywood @ \$226.86/1000 ft.^{2}

   2x4's @ \$78.00/M.b.m.

3. Unit Cost of Form

   $$\text{Plywood} - \frac{\$226.86 \times 150 \text{ ft.}^2}{1000 \text{ ft.}^2} = \$34.029$$

   $$\text{2x4's} - \frac{\$78 \times 199.3 \text{ ft.}}{1500 \text{ ft.}} = 10.364$$

   Total = \$44.393

   $$\text{Unit price} = \frac{\$44.393}{150 \text{ ft.}^2} = \$.2959/\text{ft.}^2$$

B. Labor

The labor for one and ten beams is assumed on the basis of carpenters and common laborers.

1. Carpenters @ $3.09/hr. (7)

   Make up, erecting, and stripping forms and place steel . . . . . 9 hrs/100 SFCS (12)

2. Common Laborers @ $1.90/hr. (7)

   Assisting carpenters, pouring concrete, and oiling, cleaning and moving forms . . . . 6.5 hrs/100 SFCS (12)

II. One Hundred and One Thousand Beams

A. Forms

For one hundred and one thousand beams it is assumed that the contractor would buy fabricated steel forms. The steel forms would be used on two sides of the beam and would be set on a concrete floor which would be oiled to prevent bonding of the bottom of the beam to the floor. The cost as of January 1, 1950, was $2.10 per SFCS. An increase in fabricated structural steel of 7.2% is figured for the year 1950, making the cost in January, 1951, $2.25 per SFCS.

B. Labor

The labor for one hundred and one thousand beams is assumed on the basis of structural iron workers, carpenters, and common laborers.

1. Carpenters @ \$3.09/hr. (7)

   Erecting and stripping forms . . . 3.5 hrs. (12)

2. Common Laborers @ \$1.90/hr. (7)

   Erecting, stripping, cleaning and moving forms and pouring concrete . . . . 2 hrs. (12)

3. Structural Iron Workers

   a. Conventional Beams

   An estimating handbook gives 16 hours of steel workers' labor per ton of steel for placing and tying in average in-place construction. This figure is reduced 25% to 12 hours because placing is being done on a slab on the ground, bars are all the same size in each beam, the bars are delivered bent and ready for placing, and no stirrups are required. The wage of structural iron workers in New York City in January, 1951, was \$3.25/hr. (7)

$$\text{Rate} = \frac{12 \text{ hr/ton} \times \$3.25/\text{hr}}{2000 \text{ lbs/ton}} = \$.0195/\text{lb.}$$

$$\text{Rate} = \$.0195/\text{lb.} = \$1.95/\text{cwt.}$$

   b. Prestressed Beams

   Ten minutes is allowed for two steel workers to place one strand and its two bearing assemblie Five minutes is allowed for two men to accomplish

the prestressing operation. For the bridge in Madison County, Tennessee, the engineer stated that two adjacent strands in one beam were prestressed in one operation in five minutes.

Total time = 30 min./strand

Rate = $3.25/hr.

III. Reinforcing Steel for Conventional Beams

The price of reinforcing steel is of January, 1951 (7).

		$6.39	per 100 lb.
Delivery	=	.20	per 100 lb.
Bending	=	1.75	per 100 lb.
Base Price	=	$8.34	per 100 lb.
Base Price	=	$.0834	per lb.

For 1", $1\frac{1}{8}$" and $1\frac{1}{4}$" bars, add $.001 per lb. to base price if quantity is from 1 to 5 tons. For quantities less than one ton, add $.0045 to base price.

Unit Cost:

1 to 5 tons = $.0844 per lb.

less than 1 ton = $.0879 per lb.

IV. Prestressing Strands

The costs of the prestressing strands in each case are as listed in the estimate sheets and are as quoted by John A. Roebling's Sons Co. for January, 1951. The unit prices are based on a quantity of 100 assemblies but can be

used for quantities ranging from 30 to 300. The same unit prices have been used for 1 and 10 assemblies on the assumption that the manufacturer has another order for the same size strand which will bring the total quantity within the range of 30 to 300. The same unit cost was used for 1000 assemblies, as a figure for this quantity was not available to the authors.

V. Bearing Assembly

The price per assembly is based on $6.30 cwt for steel plate and the unit price for the tube which protects the socket is $41.00 per 100 or $370.00 per 1000. The labor for cutting the hole and sizing the plate is one-half hour of steelworker time at $3.25 per hour.

CONVENTIONAL REINFORCED CONCRETE DESIGN NOTATIONS

L	Span of beam
w_{LL}	Live load
f'_c	Compressive strength of concrete at 28 days
f_c	Compressive unit stress in extreme fiber of concrete in flexure
K	$1/2\ f_c jk$
j	Ratio of distance between resultants of compressive and tensile stress to effective depth
M_{LL}	Live load moment
F	$\frac{bd^2}{12,000}$
b	Width of beam
D	Depth of beam
w_{DL}	Dead load
w_T	Dead load plus live load
M_T	Moment of dead and live load
d	Effective depth of beam
A_s	Area of steel
M_R	Resisting moment of concrete stresses
V	Total shear
v	Shearing stress
Σ_o	Sum of perimeters of bars
u	Bond stress

TABLE I

CONVENTIONAL CONCRETE BEAM DATA

TABLE F 1

CONVENTIONAL CONCRETE BEAM DATA (Cont'd)

L ft	w_{LL} psf	Neg Steel Check ft-K $M_R - M_T$	V P	v psi $\frac{V}{bjd}$	Allow. v psi	Diagonal Tension Check $v_{allow} - v$	Σo in.	u psi $\frac{V}{\Sigma o\, jd}$	Allow. u psi	Steel Used	Clear Cover in.	Quantities Steel P	Quantities Concrete cu. yd
40	500	+16.0	17000	63.2	75	+ 11.8	14.0	45.7	188	4-1 1/8" □	1.88	728.0	3.74
40	400	+ 9.0	14200	62.2	75	+ 12.8	13.2	38.0	188	6-1" φ	1.50	671.0	3.07
40	300	+27.0	11000	60.5	75	+ 14.5	13.5	44.2	188	3-1 1/8" □	1.50	546.0	2.42
40	200	+25.5	8300	51.0	75	+ 24.0	12.0	42.7	188	3-1" □	1.50	420.0	2.16
40	100	+ 0.1	5080	46.5	75	+ 28.5	9.0	40.9	188	2-1 1/2" □	1.88	364.0	1.52
30	500	+ 0.3	11700	68.7	75	+ 6.3	10.0	68.7	188	2-1 1/4" □	1.88	344.4	1.58
30	400	− 0.5	8700	65.7	75	+ 9.3	10.0	59.2	188	2-1 1/4" □	1.88	344.4	1.36
30	300	+ 1.4	6750	54.25	75	+20.8	9.0	54.2	188	2-1 1/2" □	1.50	276.0	1.11
30	200	+ 0.1	4875	53.7	75	+ 21.3	8.0	50.3	188	2-1" □	1.50	217.5	0.93
30	100	+ 1.5	3080	41.3	75	+ 33.7	6.3	37.7	188	2-1" φ	1.50	170.5	1.18
20	500	+ 3.7	6170	72.8	75	+ 2.2	6.3	80.7	188	2-1" φ	1.50	117.0	0.58
20	400	+ 4.1	5095	64.7	75	+ 10.3	6.3	72.2	188	2-1" φ	1.50	117.0	0.54
20	300	+ 1.85	3907	62.7	75	+ 12.3	4.5	83.7	188	1-1 1/2" □	1.50	95.5	0.45
20	200	+ 0.57	2625	58.[illegible]	75	+ [illegible]	4.6	72.3	[illegible]	1-1" □	1.[illegible]	74.3	0.31

PRESTRESSED CONCRETE DESIGN NOTATIONS

L Span

w_{LL} Live load

f_c Allowable compressive stress at prestressing

f'_c Allowable compressive stress under full load

f_t Allowable tensile stress at prestressing

f'_t Allowable tensile stress under full load

M_A Live load moment

n Coefficient of maximum prestress loss

D Depth of section

c Ratio of area of cable holes to area of section

Δf_t Change in f_t due to cable holes

Δf_c Change in f_c due to cable holes

$\Delta f'_t$ Change in f'_t due to cable holes

A Area of section

b Breadth of section

P Prestressing force

a Distance from bottom of beam to cable

a' Revised distance from bottom of beam to cable where the distance is less than 2.5"

P' Revised prestressing force corresponding to a'

f_b Allowable bearing pressure of bearing plate

A_b Required area of bearing plate

t_b Thickness of bearing plate

TABLE II

PRESTRESSED CONCRETE BEAM DATA

L ft	ω_{LL} ppf	f_c psi	f_c' psi	f_t psi	f_t' psi	M_A lb-in $\frac{wL^2}{8}$	n	Q $\frac{.775 f_c + f_t}{6}$	D^3 in.^{3} $\frac{2 M_A}{Q}$	D in.	k $\frac{3 wL^2}{4 f_c D}$	g $\frac{f_t}{f_c}$	g' $\frac{f_t'}{f_c}$	c %	Δf_t psi $-\frac{2}{3}ck(2+k)f_c$	Δf_c psi $-\frac{1}{3}c(1+k+k^2)f_c$	$\Delta f_t'$ psi $+\frac{2}{3}nc(1-k^2$
40	500	2200	2000	220	150	1,200,000	.85	321	7480	20.0	.341	.1	.068	2.5	-29.20	-107.0	+27.6
40	400	2200	2000	220	150	960,000	.85	321	6000	18.5	.369	.1	.068	2.5	-32.00	-110.0	+26.9
40	300	2200	2000	220	150	720 000	.85	321	4500	16.5	.413	.1	.068	2.5	-37.00	-116.0	+25.9
40	200	2200	2000	220	150	480 000	.85	321	3000	14.5	.471	.1	.068	2.5	-42.80	-124.0	+24.2
40	100	2200	2000	220	150	240 000	.85	321	1500	11.5	.593	.1	.068	2.5	-56.40	-143.0	+20.2
30	500	2200	2000	220	150	675 000	.85	321	5240	17.5	.217	.1	.068	2.5	-17.80	-92.9	+29.7[illegible]
30	400	2200	2000	220	150	540 000	.85	321	4190	16.5	.232	.1	.068	2.5	-19.00	-94.3	+29.8[illegible]
30	300	2200	2000	220	150	405 000	.85	321	3145	15.0	.256	.1	.068	2.5	-21.20	-97.0	+29.[illegible]
30	200	2200	2000	220	150	270,000	.85	321	2020	13.0	.295	.1	.068	2.5	-24.80	-100.7	+28.4[illegible]
30	100	2200	2000	220	150	135 000	.85	321	842	9.5	.403	.1	.068	2.5	-35.60	-114.8	+26.10
20	500	2200	2000	220	150	300 000	.85	321	1940	12.5	.136	.1	.068	2.5	-10.68	-84.3	+30.3[illegible]
20	400	2200	2000	220	150	240000	.85	321	1553	11.5	.148	.1	.068	2.5	-11.68	-86.[illegible]	+30.5[illegible]
20	300	2200	2000	220	150	180 000	.85	321	11[illegible]5	10.5	.163	.1	.068	2.5	-12.90	-87.2	+30.4[illegible]
20	200	2200	2000	220	150	120 000	.85	321	750	9.5	.180	.1	.068	2.5	-14.40	-88.9	+30.2[illegible]

TABLE [illegible]

PRESTRESSED CONCRETE BEAM DATA (Cont'd)

L	w_{LL}	f_{t1} (Revised)	f_{t1} (Revised)	f'_{t1} (Revised)	k	γ	γ'	A	b	P	a	a'	P'	Strand	f_b	A_b	t_b	Plate Size	Section b	Section D	C[illegible]
ft	ppf	psi	psi	psi				ft^2	in	p	in	in	p		psi	$in.^2$	in		in	in	[illegible]
		$f_t-\Delta f_t$	$f_t-\Delta f_t$	$f'_t-\Delta f'_t$	$\frac{3wL^2}{4f_{c1}D}$	$\frac{f_{t1}}{f_{c1}}$	$\frac{f'_{t1}}{f_{c1}}$								$.55\,f'_c$	$\frac{P}{f_b}$					
40	500	2093.0	190.8	177.6	.359	.092	.084	1.340	10.0	190,000	3.37	—	—	2-1¼"	2750	69.1	¾	10x20	10.0	20.0	2.[illegible]
40	400	20[illegible].0	138.0	176.9	.389	.090	.085	1.18[illegible]	9.5	167,500	2.91	—	—	1-1⅝"	2750	66.8	¾	9½x10	9.5	11.5	1.[illegible]
40	300	2084.[illegible]	123.0	175.9	.436	.088	.084	1.000	9.0	141,[illegible]00	2.34	2.50	144,500	1-1 9/16"	2750	51.5	½	9x9	9.0	16.5	1.[illegible]
40	200	2076.0	117.2	174.2	.498	.085	.084	.712	8.0	110,000	1.75	2.50	115,000	1-1⅜"	2750	40.0	½	8x8	8.0	14.5	1.[illegible]
40	100	2051.0	163.6	170.2	.635	.080	.083	.507	6.5	76,500	0.85	2.50	92,000	1-1¼"	2750	25.6	½	6½x6½	6.5	11.5	0.[illegible]
30	500	2107.1	202.2	177.7	.229	.096	.085	.848	7.0	116,200	3.73	—	—	1-1⅜"	2750	42.3	½	7x7	7.0	17.5	0.[illegible]
30	400	2105.7	201.0	179.8	.243	.096	.085	.717	6.5	101,900	3.38	—	—	1-1 5/16"	2750	37.1	½	6½x6½	6.5	16.5	0.8[illegible]
30	300	2103.0	198.8	179.2	.268	.094	.085	.577	6.0	85,700	3.00	—	—	1-1 3/16"	2750	31.2	½	6x6	6.0	15.0	0.7[illegible]
30	200	2079.3	19[illegible].2	178.5	.309	.093	.085	.464	5.5	6[illegible],000	3.64	—	—	1-1 1/16"	2750	24.7	½	5½x6	5.5	13.0	[illegible]
30	100	20[illegible]	184.4	176.1	.425	.089	.085	.325	5.0	45,[illegible]	1.38	2.63	60,150	1-1"	2750	16.4	½	5x5	5.0	9.5	[illegible]
20	500	2115.0	207.3	180.3	.141	.099	.085	.517	6.0	71,500	3.[illegible]	—	—	1-1⅛"	2750	26.0	½	6x6	6.0	12.5	0.37
20	400	2114.0	20[illegible].3	180.5	.151	.099	.085	.4[illegible]2	6.0	65,700	4.26	—	—	1-1 1/16"	2750	23.9	½	6x6	6.0	11.[illegible]	0.3[illegible]
20	300	211[illegible]	209.1	180.4	.169	.099	.086	.313	5.5	54,80[illegible]	2.[illegible]	—	—	1-1"	2750	19.9	½	5½x6	5.5	10.5	0.3[illegible]
20	200	20[illegible].1	205.6	180.2	.127	.097	.085	.274	4.5	40,700	2.20	—	—	1-1"	2750	14.8	½	4½x5	4.5	9.5	0.22

JOHN A. ROEBLING'S SONS COMPANY
BRIDGE DIVISION
TRENTON, NEW JERSEY

SUBJECT: PRESTRESSED-CONCRETE STRAND
PHYSICAL PROPERTIES

Dia. (Ins.)	Wgt. per Ft. (Lb.)	Area (Sq. Ins.)	Min. Guaranteed Ultimate Strength (Lb.)	Design Load (105,000 psi) (Lb)	Tensioning Load (120,000 psi) (Lb.)
0.600	0.737	0.215	46,000	22,500	26,000
1	2.00	0.577	122,000	60,500	69,500
1-1/16	2.30	0.663	138,000	69,500	79,500
1-1/8	2.61	0.751	156,000	79,000	90,000
1-3/16	2.92	0.843	172,000	88,500	101,000
1-1/4	3.22	0.931	192,000	98,000	111,500
1-5/16	3.58	1.04	212,000	109,500	125,000
1-3/8	3.89	1.12	232,000	117,500	134,500
1-7/16	4.29	1.24	252,000	130,500	149,000
1-1/2	4.70	1.36	276,000	143,000	163,500
1-9/16	5.11	1.48	300,000	155,500	177,500
1-5/8	5.52	1.60	324,000	168,000	192,000

JRHicks:dym
11-17-50

Form 775-10

COST ESTIMATE SHEETS FOR CONVENTIONAL AND PRESTRESSED BEAMS

The following pages, 26 through 81, are the sheets on which the costs of the fourteen conventional and fourteen prestressed beams are estimated for the quantities of 1, 10, 100 and 1000 beams.

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 200 ppf Section 12.5" x 5" Cu Yds Concrete .309 Lbs Reinforced Steel 74.3

ITEM Material	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$ .296	50	100	$14.80	$29.60	$ 7.40	$ 29.60
Reinforcing Bars	Pound	$ .0879	74.3	743	6.54	65.40	6.54	65.40
Ready Mix Concrete	Cu. Yd.	$11.15	.309	3.09	3.45	34.45	3.45	34.45
Total-Mat'l.							$17.39	$129.45
ITEM Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Carpenter	Hour	9	$3.09	.50	1	10	$13.90	$139.00
Common Labor	Hour	6.5	1.90	.50	1	10	6.18	61.75
Total-Labor							$19.68	$196.75
TOTAL							$36.97	$325.20

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 20' Load 200 ppf Section 9.5" x 4.5" Cu Yds Concrete 0.22 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	39.20	78.40	$11.60	$23.20	$ 5.80	$ 23.20
Strand							40.50	405.00
Bearing Assembly							2.42	24.20
Ready Mix Concrete	Cu. Yd.	$11.15	0.22	2.2			2.46	24.60
Total-Mat'l.							$51.18	$477.00
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.392	1	10	$10.90	$109.00
Common Labor	Hour	6.5	$1.90	.392	1	10	4.83	48.30
Total-Labor							$15.73	$157.30
TOTAL							$66.91	$634.30

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 200 ppf Section 12.5"x5" Cu Yds Concrete .309 Lbs Reinforced Steel 74.3

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	400	2,000	$900.00	$4500.00	$ 9.00	$ 90.00
Reinforcing Bars	Pound	$.0844	7,430	74,300	-	-	627.00	6,271.00
Ready Mix Concrete	Cu. Yd.	$11.15	30.9	309	-	-	344.50	3,445.00
Total-Mat'l.							$ 980.50	$ 9,806.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	.4	-	-	$ 432.00	$ 4,320.00
Common Labor	Hour	$1.90	2	.4	-	-	152.00	1,520.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	74.3	743.0	144.90	1,449.00
Total-Labor							$ 728.90	$ 7,289.00
TOTAL							$1,709.40	$17,095.00

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 200 psf Section 9.5"x4.5" Cu Yds Concrete 0.22 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	317	1585	$714.00	$3570.00	$ 7.14	$ 71.40
Strand							4,050.00	40,500.00
Bearing Assembly							242.00	2,390.00
Ready Mix Concrete	Cu. Yd.	$11.15	22	220			246.00	2,460.00
Total-Mat'l.							$4,545.14	$45,421.40
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	$3.09	3.5	.317			$ 342.50	$ 3,425.00
Common Labor	Hour	$1.90	2	.317			120.30	1,203.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 625.30	$ 6,253.00
TOTAL							$5,170.44	$51,674.40

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 300 psf Section 14.5"x6" Cu Yds Concrete .447 Lbs Reinforced Steel 95.5

ITEM					COST		COST ALLOTTED	
Material	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$ .296	58.3	166.6	$17.26	$34.52	$ 8.63	$ 34.52
Reinforcing Bars	Pound	$ .0879	95.5	955	-	-	8.40	84.00
Ready Mix Concrete	Cu. Yd.	$11.15	.447	4.47	-	-	4.98	49.80
Total-Mat'l.							$21.91	$168.32
ITEM					No. Assemblies & Disassemblies			
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	1 Form	2 Forms		
Carpenter	Hour	9	$3.09	.58	1	10	$15.66	$156.60
Common Labor	Hour	6.5	1.90	.58	1	10	7.16	71.60
Total-Labor							$22.82	$228.20
TOTAL							$44.49	$393.12

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 20' Load 300 ppf Section 10.5"x5.5" Cu Yds Concrete 0.30 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	44.2	88.4	$13.10	$26.20	$ 6.55	$ 26.20
Strand							40.50	405.00
Bearing Assembly							2.63	26.30
Ready Mix Concrete	Cu. Yd.	$11.15	0.30	3.0			3.35	33.50
Total-Mat'l.							$53.03	$491.00
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.442	1	10	$12.29	$122.90
Common Labor	Hour	6.5	$1.90	.442	1	10	5.46	54.60
Total-Labor							$17.75	$177.50
TOTAL							$70.78	$668.50

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 300 ppf Section 14.5"x6" Cu Yds Concrete .447 Lbs Reinforced Steel 95.5

ITEM Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	 50 Forms	COST ALLOTTED (10 Forms) 100 Beams	 (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	483.2	2,416	$1087.00	$5436.00	$ 10.87	$ 108.70
Reinforcing Bars	Pound	$.0844	9,550	95,500	-	-	806.00	8,060.00
Ready Mix Concrete	Cu. Yd.	$11.15	44.7	447	-	-	498.41	4,984.10
Total-Mat'l.							$1,315.28	$13,152.80
ITEM Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Carpenters	Hour	$3.09	3.5	.483	-	-	$ 522.00	$ 5,220.00
Common Labor	Hour	$1.90	2	.483	-	-	183.54	1,835.40
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	95.5	955	187.20	1,872.00
Total-Labor							$ 892.74	$ 8,927.40
TOTAL							$2,208.02	$22,080.20

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 300 ppf Section 10.5"x5.5" Cu Yds Concrete 0.30 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	350	1750	$787.00	$3935.00	$ 7.87	$ 78.70
Strand							4,050.00	40,500.00
Bearing Assembly							263.00	2,600.00
Ready Mix Concrete	Cu. Yd.	$11.15	30	300			335.00	3,350.00
Total-Mat'l.							$4,655.87	$46,528.70
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	$3.09	3.5	.35			$ 378.00	$ 3,780.00
Common Labor	Hour	$1.90	2	.35			133.00	1,330.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 673.50	$ 6,735.00
TOTAL							$5,329.37	$53,263.70

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

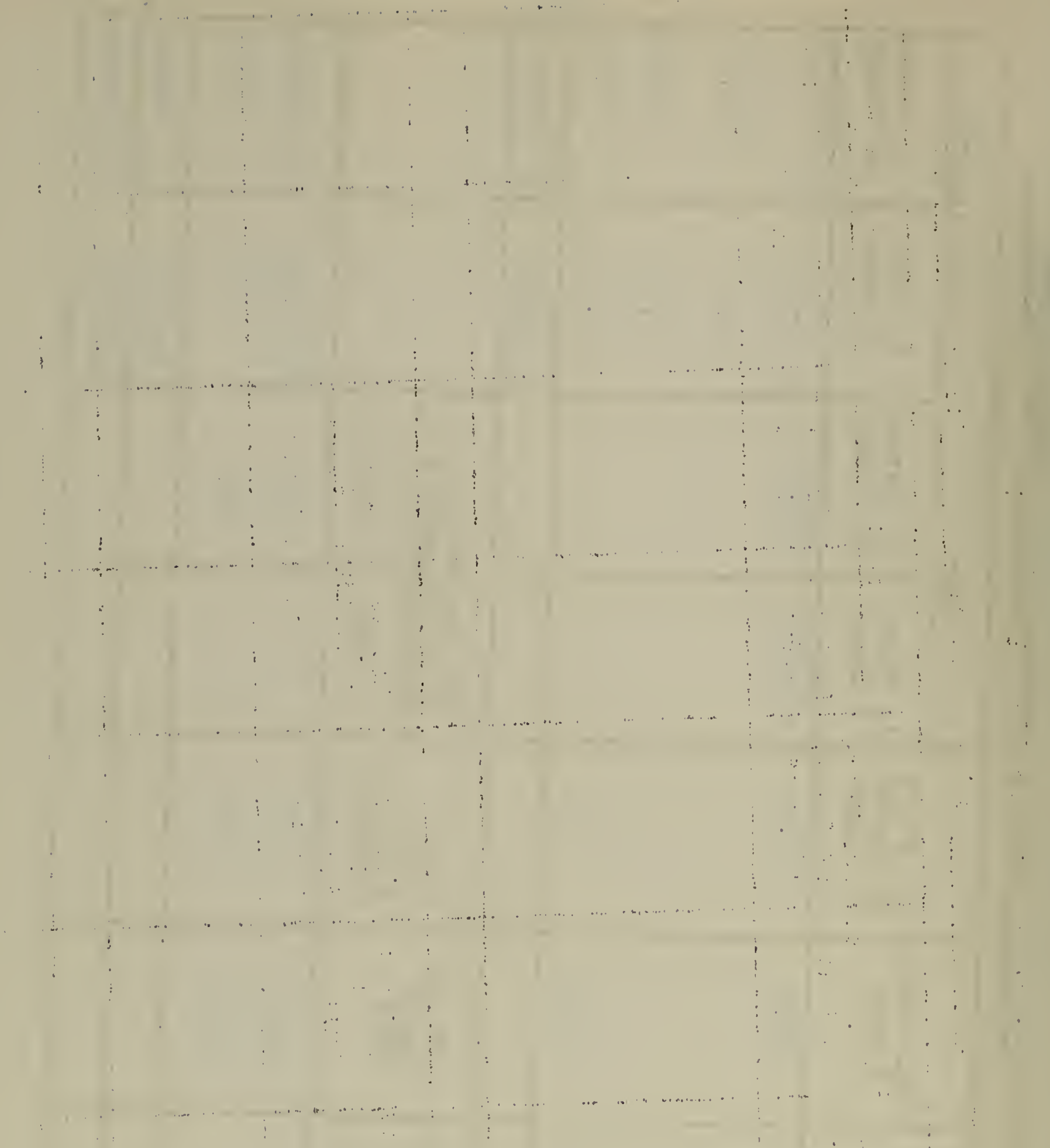
Length 20' Load 400 ppf Section 15" x 7" Cu Yds Concrete .54 Lbs Reinforced Steel 117

ITEM / Material	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$.296	61.66	123.32	$18.25	$36.50	$ 9.13	$ 36.50
Reinforcing Bars	Pound	$.0879	117	1170	-	-	10.28	102.80
Ready Mix Concrete	Cu. Yd.	$11.15	.54	5.40	-	-	6.02	60.20
Total-Mat'l.							$25.43	$199.50
ITEM / Labor	**Unit**	**No. Units per 100 S.F.C.S. per Beam**	**Cost per Labor Unit**	**No. of 100 S.F.C.S. per Beam**	**No. Assemblies & Disassemblies: 1 Form**	**No. Assemblies & Disassemblies: 2 Forms**		
Carpenter	Hour	9	$3.09	.62	1	10	$17.26	$172.60
Common Labor	Hour	6.5	$1.90	.62	1	10	7.66	76.60
Total-Labor							$24.92	$249.20
TOTAL							$50.35	$448.70

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 20' Load 400 ppf Section 11.5"x6" Cu Yds Concrete 0.36 Strand $1\text{-}1\frac{1}{16}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	48.4	96.8	$14.30	$28.60	$ 7.15	$ 28.60
Strand							73.60	736.00
Bearing Assembly							2.68	26.80
Ready Mix Concrete	Cu. Yd.	$11.15	0.36	3.6			4.02	40.20
Total-Mat'l.							$ 87.45	$ 831.60
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.484	1	10	$ 13.45	$ 134.50
Common Labor	Hour	6.5	$1.90	.484	1	10	5.97	59.70
Total-Labor							$ 19.42	$ 194.20
TOTAL							$106.87	$1,025.80



COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 400 ppf Section 15" x 7" Cu Yds Concrete .54 Lbs Reinforced Steel 117

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	500	2,500	$1125.00	$5625.00	$ 11.25	$ 112.50
Reinforcing Bars	Pound	$.0844	11,700	117,000	-	-	987.50	9,875.00
Ready Mix Concrete	Cu. Yd.	$11.15	54	540	-	-	602.10	6,021.00
Total-Mat'l.							$1,600.85	$16,008.50
ITEM Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Carpenters	Hour	$3.09	3.5	.5	-	-	$ 540.00	$ 5,400.00
Common Labor	Hour	$1.90	2	.5	-	-	190.00	1,900.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	117	1170	228.00	2,280.00
Total-Labor							$ 958.00	$ 9,580.00
TOTAL							$2,558.85	$25,588.50

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 400 ppf Section 11.5"x6" Cu Yds Concrete 0.36 Strand $1\text{-}1\frac{1}{16}$"

ITEM / Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST: 10 Forms	TOTAL FORM COST: 50 Forms	COST ALLOWED: (10 Forms) 100 Beams	COST ALLOWED: (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	383.5	1917.5	$862.00	$4310.00	$ 8.62	$ 86.20
Strand							7,360.00	73,600.00
Bearing Assembly							268.00	2,650.00
Ready Mix Concrete	Cu. Yd.	$11.15	36.0	360.0			402.00	4,020.00
Total-Mat'l.							$8,038.62	$80,356.20
ITEM / Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Carpenters	Hour	$3.09	3.5	.3835			$ 414.00	$ 4,140.00
Common Labor	Hour	$1.90	2	.3835			145.80	1,458.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 722.30	$ 7,223.00
TOTAL							$8,760.92	$87,579.20

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 500 psf Section 16" x 7" Cu Yds Concrete .576 Lbs Reinforced Steel 117

ITEM					COST		COST ALLOTTED	
Material	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$.296	65	130	$19.24	$38.48	$ 9.62	$ 38.48
Reinforcing Bars	Pound	$.0879	117	1170	-	-	10.28	102.80
Ready Mix Concrete	Cu. Yd.	$11.15	.576	5.76	-	-	6.42	64.22
Total-Mat'l.							$26.32	$205.50
ITEM					No. Assemblies & Disassemblies			
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	1 Form	2 Forms		
Carpenter	Hour	9	$3.09	.65	1	10	$18.07	$180.70
Common Labor	Hour	6.5	$1.90	.65	1	10	8.03	80.30
Total-Labor							$26.10	$261.00
TOTAL							$52.42	$466.50

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 20' Load 500 ppf Section 12.5"x6" Cu Yds Concrete 0.39 Strand 1-1$\frac{1}{8}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Flywood Forms	S.F.C.S.	$.296	51.7	103.4	$15.30	$30.60	$ 7.65	$ 30.60
Strand							78.45	784.50
Bearing Assembly							2.68	26.80
Ready Mix Concrete	Cu. Yd.	$11.15	0.39	3.90			4.35	43.50
Total-Mat'l.							$ 93.13	$ 885.40
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.517	1	10	$ 14.39	$ 143.90
Common Labor	Hour	6.5	$1.90	.517	1	10	6.38	63.80
Total-Labor							$ 20.77	$ 207.70
TOTAL							$113.90	$1,093.10

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 500 ppf Section 16" x 7" Cu Yds Concrete .576 Lbs Reinforced Steel 117

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	534	2670	$1201.50	$6007.50	$ 12.02	$ 120.20
Reinforcing Bars	Pound	$.084	11,700	117,000	-	-	987.50	9,875.00
Ready Mix Concrete	Cu. Yd.	$11.15	57.6	576	-	-	642.24	6,422.40
Total-Mat'l.							$1,641.76	$16,417.60
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	.534	-	-	$ 576.00	$ 5,760.00
Common Labor	Hour	$1.90	2	.534	-	-	202.92	2,029.20
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	117	1170	228.00	2,280.00
Total-Labor							$1,006.92	$10,069.20
TOTAL							$2,648.68	$26,486.80

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 500 psf Section 12.5"x6" Cu Yds Concrete 0.39 Strand $1\text{-}1\frac{1}{2}$"

ITEM Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	417	2085	$939.00	$4695.00	$ 9.39	$ 93.90
Strand							7,845.00	78,450.00
Bearing Assembly							263.00	2,620.00
Ready Mix Concrete	Cu. Yd.	$11.15	39	390			435.00	4,350.00
Total-Mat'l.							$8,557.39	$85,513.90
ITEM Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Carpenters	Hour	$3.09	3.5	.417			$ 451.00	$ 4,510.00
Common Labor	Hour	$1.90	2	.417			158.20	1,582.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 771.70	$ 7,717.00
TOTAL							$9,329.09	$93,230.90

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 100 ppf Section 7.5"x13.5" Cu Yds Concrete .781 Lbs Reinforced Steel 170.5

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTED (1 Form) 1 Beam	COST ALLOTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	86.25	172.5	$25.53	$51.06	$12.76	$ 51.06
Reinforcing Bars	Pound	$.0879	170.5	1705	15.00	150.00	15.00	150.00
Ready Mix Concrete	Cu. Yd.	$11.15	.781	7.81	8.70	87.00	8.70	87.00
Total-Mat'l.							$36.46	$288.06
ITEM	**Unit**	**No. Units per 100 S.F.C.S. per Beam**	**Cost per Labor Unit**	**No. of 100 S.F.C.S. per Beam**	**No. Assemblies & Disassemblies 1 Form**	**No. Assemblies & Disassemblies 2 Forms**		
Labor								
Carpenter	Hour	9	$3.09	.8625	1	10	$23.99	$239.90
Common Labor	Hour	6.5	$1.90	.8625	1	10	10.64	106.40
Total-Labor							$34.63	$346.30
TOTAL							$71.09	$634.36

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 100 ppf Section 9.5"x5" Cu Yds Concrete 0.37 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	60.0	120.0	$17.75	$35.50	$ 8.88	$ 35.50
Strand							46.75	467.50
Bearing Assembly							2.49	24.90
Ready Mix Concrete	Cu. Yd.	$11.15	0.37	3.7			4.13	41.30
Total-Mat'l.							$62.25	$569.20
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.60	1	10	$16.68	$166.80
Common Labor	Hour	6.5	$1.90	.60	1	10	7.41	74.10
Total-Labor							$24.09	$240.90
TOTAL							$86.34	$810.10

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 100 psf Section 7.5"x13.5" Cu Yds Concrete .781 Lbs Reinforced Steel 170.5

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	675	3,375	$1519.00	$7595.00	$ 15.19	$ 151.90
Reinforcing Bars	Pound	$.0844	17,050	170,500	-	-	1,439.00	14,390.00
Ready Mix Concrete	Cu. Yd.	$11.15	78.1	781	-	-	870.00	8,700.00
Total-Mat'l.							$2,324.19	$23,241.90
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	.675	-	-	$ 729.00	$ 7,290.00
Common Labor	Hour	$1.90	2	.675	-	-	257.00	2,570.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	170.5	1705	332.50	3,325.00
Total-Labor							$1,318.50	$13,185.00
TOTAL							$3,642.69	$36,426.90

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 100 psf Section 9.5"x5" Cu Yds Concrete 0.37 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	476	2380	$1070.00	$5350.00	$ 10.70	$ 107.00
Strand							4,675.00	46,750.00
Bearing Assembly							249.00	2,460.00
Ready Mix Concrete	Cu. Yd.	$11.15	37.0	370.0			413.00	4,130.00
Total-Mat'l.							$5,347.70	$53,447.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	$3.09	3.5	.476			$ 514.50	$ 5,145.00
Common Labor	Hour	$1.90	2	.476			181.40	1,814.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 858.40	$ 8,584.00
TOTAL							$6,206.10	$62,031.00

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 200 psf Section 7.5"x16" Cu Yds Concrete .925 Lbs Reinforced Steel 217.5

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTED (1 Form) 1 Beam	COST ALLOTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	98.7	197.4	$29.20	$58.40	$14.60	$ 58.40
Reinforcing Bars	Pound	$.0879	217.5	2175	-	-	19.13	191.30
Ready Mix Concrete	Cu. Yd.	$11.15	.925	9.25	-	-	10.31	103.10
Total-Mat'l.							$44.04	$352.80
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.9875	1	10	$27.42	$274.20
Common Labor	Hour	6.5	$1.90	.9875	1	10	12.19	121.90
Total-Labor							$39.61	$396.10
TOTAL							$83.65	$748.90

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 200 ppf Section 13"x5.5" Cu Yds Concrete 0.55 Strand 1-1$\frac{1}{16}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	78.75	157.50	$23.30	$46.60	$11.65	$ 46.60
Strand							80.50	805.00
Bearing Assembly							2.63	26.30
Ready Mix Concrete	Cu. Yd.	$11.15	0.55	5.5			6.13	61.30
Total-Mat'l.							$100.91	$ 939.20
ITEM	**Unit**	**No. Units per 100 S.F.C.S. per Beam**	**Cost per Labor Unit**	**No. of 100 S.F.C.S. per Beam**	**No. Assemblies & Disassemblies: 1 Form**	**No. Assemblies & Disassemblies: 2 Forms**		
Labor								
Carpenter	Hour	9	$3.09	.7875	1	10	$ 21.90	$ 219.00
Common Labor	Hour	6.5	$1.90	.7875	1	10	9.71	97.10
Total-Labor							$ 31.61	$ 316.10
TOTAL							$132.52	$1,255.30

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 200 ppf Section 7.5"x16" Cu Yds Concrete .925 Lbs Reinforced Steel 217.5

ITEM / Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOTTED (10 Forms) 100 Beams	COST ALLOTTED (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	800	4,000	$1800.00	$9000.00	$ 18.00	$ 180.00
Reinforcing Bars	Pound	$.0844	21,750	217,500	-	-	1,837.00	18,370.00
Ready Mix Concrete	Cu. Yd.	$11.15	92.5	925	-	-	1,031.00	10,310.00
Total-Mat'l.							$2,886.00	$28,860.00
ITEM / Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**Cwt. of Steel for 100 Beams**	**Cwt. of Steel for 1000 Beams**		
Carpenters	Hour	$3.09	3.5	.8	-	-	$ 864.00	$ 8,640.00
Common Labor	Hour	$1.90	2	.8	-	-	304.00	3,040.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	217.5	2175.0	424.00	4,240.00
Total-Labor							$1,592.00	$15,920.00
TOTAL							$4,478.00	$44,780.00

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 200 ppf Section 13"x5.5" Cu Yds Concrete 0.55 Strand 1-1 1/16"

ITEM — Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	650	3250	$1462.50	$7312.50	$ 14.62	$ 146.20
Strand							8,050.00	80,500.00
Bearing Assembly							263.00	2,600.00
Ready Mix Concrete	Cu. Yd.	$11.15	55	550			613.00	6,130.00
Total-Mat'l.							$ 8,940.62	$ 89,378.20
ITEM — Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Carpenters	Hour	$3.09	3.5	.65			$ 702.00	$ 7,020.00
Common Labor	Hour	$1.90	2	.65			247.00	2,470.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,111.50	$ 11,115.00
TOTAL							$10,052.12	$100,493.20

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 300 psf Section 8" x 18" Cu Yds Concrete 1.11 Lbs Reinforced Steel 276.0

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	110	220	$32.55	$65.10	$16.28	$ 65.10
Reinforcing Bars	Pound	$.0879	276	2760	-	-	24.30	243.00
Ready Mix Concrete	Cu. Yd.	$11.15	1.11	11.10	-	-	12.38	123.80
Total-Mat'l.							$52.96	$431.90
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.1	1	10	$30.59	$305.90
Common Labor	Hour	6.5	$1.90	1.1	1	10	13.59	135.90
Total-Labor							$44.18	$441.80
TOTAL							$97.14	$873.70

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 300 ppf Section 15" x 6" Cu Yds Concrete 0.70 Strand 1-1 $\frac{3}{16}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	90.0	180.0	$26.60	$53.20	$ 13.30	$ 53.20
Strand							90.45	904.50
Bearing Assembly							2.68	26.80
Ready Mix Concrete	Cu. Yd.	$11.15	0.70	7.0			7.81	78.10
Total-Mat'l.							$114.24	$1,062.60
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	.90	1	10	$ 25.05	$ 250.50
Common Labor	Hour	6.5	$1.90	.90	1	10	11.12	111.20
Total-Labor							$ 36.17	$ 361.70
TOTAL							$150.41	$1,424.30

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 300 ppf Section 8" x 18" Cu Yds Concrete 1.11 Lbs Reinforced Steel 276.0

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	900	4500	$2025.00	$10125.00	$ 20.25	$ 202.50
Reinforcing Bars	Pound	$.0844	27,600	276,000	-	-	2,230.00	22,300.00
Ready Mix Concrete	Cu. Yd.	$11.15	111	1,110	-	-	1,238.00	12,380.00
Total-Mat'l.							$3,488.25	$34,882.50
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	.9	-	-	$ 972.00	$ 9,720.00
Common Labor	Hour	$1.90	2	.9	-	-	342.00	3,420.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	276	2760	538.00	5,380.00
Total-Labor							$1,852.00	$18,520.00
TOTAL							$5,340.25	$53,402.50

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 300 ppf Section 15"x6" Cu Yds Concrete 0.70 Strand 1-1 3/16"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	750	3750	$1690.00	$8450.00	$ 16.90	$ 169.00
Strand							9,045.00	90,450.00
Bearing Assembly							268.00	2,650.00
Ready Mix Concrete	Cu. Yd.	$11.15	70	700			781.00	7,810.00
Total-Mat'l.							$10,110.90	$101,079.00
ITEM Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Carpenters	Hour	$3.09	3.5	.75			$ 810.00	$ 8,100.00
Common Labor	Hour	$1.90	2	.75			285.00	2,850.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,257.50	$ 12,575.00
TOTAL							$11,368.40	$113,654.00

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 400 psf Section 9"x19.5" Cu Yds Concrete 1.36 Lbs Reinforced Steel 344.4

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTED (1 Form) 1 Beam	COST ALLOTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	120	240	$35.55	$71.10	$ 17.78	$ 71.10
Reinforcing Bars	Pound	$.0879	344.4	3444	-	-	30.30	303.00
Ready Mix Concrete	Cu. Yd.	$11.15	1.36	13.6	-	-	15.17	151.70
Total-Mat'l.							$ 63.25	$ 525.80
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.20	1	10	$ 33.35	$ 333.50
Common Labor	Hour	6.5	$1.90	1.20	1	10	14.83	148.30
Total-Labor							$ 48.18	$ 481.80
TOTAL							$111.43	$1007.60

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 400 ppf Section 16.5"x6.5" Cu Yds Concrete 0.83 Strand 1-1 5/16"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	98.75	197.50	$29.20	$58.40	$ 14.60	$ 58.40
Strand							108.15	1,081.50
Bearing Assembly							2.79	27.90
Ready Mix Concrete	Cu. Yd.	$11.15	0.83	8.30			9.26	92.60
Total-Mat'l.							$134.80	$1,260.40
ITEM / Labor	**Unit**	**No. Units per 100 S.F.C.S. per Beam**	**Cost per Labor Unit**	**No. of 100 S.F.C.S. per Beam**	**No. Assemblies & Disassemblies** 1 Form	2 Forms		
Carpenter	Hour	9	$3.09	.9875	1	10	$ 27.45	$ 274.50
Common Labor	Hour	6.5	$1.90	.9875	1	10	12.19	121.90
Total-Labor							$ 39.64	$ 396.40
TOTAL							$174.44	$1,656.80

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 400 psf Section 9"x19.5" Cu Yds Concrete 1.36 Lbs Reinforced Steel 344.4

ITEM / Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST: 10 Forms	TOTAL FORM COST: 50 Forms	COST ALLOWED: (10 Forms) 100 Beams	COST ALLOWED: (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	975	4,875	$2193.00	$10965.00	$ 21.93	$ 219.30
Reinforcing Bars	Pound	$.0844	34,440	344,400	-	-	2,908.00	29,080.00
Ready Mix Concrete	Cu. Yd.	$11.15	136	1,360	-	-	1,517.00	15,170.00
Total-Mat'l.							$4,446.93	$44,469.30
ITEM / Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**Cwt. of Steel for 100 Beams**	**Cwt. of Steel for 1000 Beams**		
Carpenters	Hour	$3.09	3.5	.975	-	-	$1,054.00	$10,540.00
Common Labor	Hour	$1.90	2	.975	-	-	370.00	3,700.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	344.4	3,444	672.00	6,720.00
Total-Labor							$2,096.00	$20,960.00
TOTAL							$6,542.93	$65,429.30

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 400 ppf Section 16.5"x6.5" Cu Yds Concrete 0.83 Strand $1\text{-}1\frac{5}{16}$"

ITEM Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	825	4125	$1855.00	$9275.00	$ 18.55	$ 185.50
Strand							10,815.00	108,150.00
Bearing Assembly							279.00	2,760.00
Ready Mix Concrete	Cu. Yd.	$11.15	83	830			926.00	9,260.00
Total-Mat'l.							$12,038.55	$120,355.50
ITEM Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Carpenters	Hour	$3.09	3.5	.825			$ 891.00	$ 8,910.00
Common Labor	Hour	$1.90	2	.825			313.50	3,135.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,367.00	$ 13,670.00
TOTAL							$13,405.55	$134,025.50

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 500 ppf Section 10"x20.5" Cu Yds Concrete 1.58 Lbs Reinforced Steel 344.4

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	127.5	255	$37.75	$75.50	$ 18.86	$ 75.50
Reinforcing Bars	Pound	$.0879	344.4	3444	-	-	30.30	303.00
Ready Mix Concrete	Cu. Yd.	$11.15	1.58	15.8	-	-	17.61	176.10
Total-Mat'l.							$ 66.77	$ 554.60
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.275	1	10	$ 35.40	$ 354.00
Common Labor	Hour	6.5	$1.90	1.275	1	10	15.75	157.50
Total-Labor							$ 51.15	$ 511.50
TOTAL							$117.92	$1,066.10

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 500 psf Section 17.5"x7" Cu Yds Concrete 0.95 Strand 1-1 3/8"

ITEM / Material	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$.296	105.05	210.10	$31.10	$62.20	$ 15.55	$ 62.20
Strand							115.00	1,150.00
Bearing Assembly							2.91	29.10
Ready Mix Concrete	Cu. Yd.	$11.15	0.95	9.50			10.59	105.90
Total-Mat'l.							$144.05	$1,347.20
ITEM / Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies: 1 Form	No. Assemblies & Disassemblies: 2 Forms		
Carpenter	Hour	9	$3.09	1.05	1	10	$ 29.20	$ 292.00
Common Labor	Hour	6.5	$1.90	1.05	1	10	12.97	129.70
Total-Labor							$ 42.17	$ 421.70
TOTAL							$186.22	$1,768.90

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 500 ppf Section 10"x20.5" Cu Yds Concrete 1.58 Lbs Reinforced Steel 344.4

ITEM / Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST: 10 Forms	TOTAL FORM COST: 50 Forms	COST ALLOTTED: (10 Forms) 100 Beams	COST ALLOTTED: (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,050	5,250	$2361.00	$11805.00	$ 23.61	$ 236.10
Reinforcing Bars	Pound	$.0844	34,440	344,400	-	-	2,908.00	29,080.00
Ready Mix Concrete	Cu. Yd.	$11.15	158	1,580	-	-	1,760.00	17,600.00
Total-Mat'l.							$4,691.61	$46,916.10
ITEM / Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**Cwt. of Steel for 100 Beams**	**Cwt. of Steel for 1000 Beams**		
Carpenters	Hour	$3.09	3.5	1.05	-	-	$1,135.00	$11,350.00
Common Labor	Hour	$1.90	2	1.05	-	-	399.00	3,990.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	344.4	3,444	672.00	6,720.00
Total-Labor							$2,206.00	$22,060.00
TOTAL							$6,897.61	$68,976.10

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 500 ppf Section 17.5"x7" Cu Yds Concrete 0.95 Strand 1-1$\frac{3}{8}$"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	875	4,375	$1970.00	$9850.00	$ 19.70	$ 197.00
Strand							11,500.00	115,000.00
Bearing Assembly							291.00	2,880.00
Ready Mix Concrete	Cu. Yd.	$11.15	95	950			1,059.00	10,590.00
Total-Mat'l.							$12,869.70	$128,667.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	$3.09	3.5	.875			$ 948.00	$ 9,480.00
Common Labor	Hour	$1.90	2	.875			333.50	3,335.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,454.00	$ 14,540.00
TOTAL							$14,323.70	$143,207.00

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 100 ppf Section 8"x18.5" Cu Yds Concrete 1.52 Lbs Reinforced Steel 364

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	150	300	$44.35	$88.70	$ 22.18	$ 88.70
Reinforcing Bars	Pound	$.0879	364	3640	-	-	32.00	320.00
Ready Mix Concrete	Cu. Yd.	$11.15	1.52	15.2	-	-	16.95	169.50
Total-Mat'l.							$ 71.13	$ 578.20
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.502	1	10	$ 41.75	$ 417.50
Common Labor	Hour	6.5	$1.90	1.502	1	10	18.58	185.80
Total-Labor							$ 60.33	$ 603.30
TOTAL							$131.46	$1,181.50

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 100 ppf Section 11.5"x6.5" Cu Yds Concrete 0.77 Strand 1-1$\frac{1}{4}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
Material					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$.296	98.3	196.6	$29.10	$58.20	$ 14.55	$ 58.20
Strand							108.90	1,089.00
Bearing Assembly							2.79	27.90
Ready Mix Concrete	Cu. Yd.	$11.15	0.77	7.7			8.59	85.90
Total-Mat'l.							$134.83	$1,261.00
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	$3.09	.983	1	10	$ 27.35	$ 273.50
Common Labor	Hour	6.5	$1.90	.983	1	10	12.13	121.30
Total-Labor							$ 39.48	$ 394.80
TOTAL							$174.31	$1,655.80

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 100 ppf Section 8"x18.5" Cu Yds Concrete 1.52 Lbs Reinforced Steel 364

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,232	6,160	$2773.00	$13865.00	$ 27.73	$ 277.30
Reinforcing Bars	Pound	$.0844	36,400	364,000	-	-	3,072.00	30,720.00
Ready Mix Concrete	Cu. Yd.	$11.15	152	1,520	-	-	1,695.00	16,950.00
Total-Mat'l.							$4,794.73	$47,947.30
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	1.232	-	-	$1,330.00	$13,300.00
Common Labor	Hour	$1.90	2	1.232	-	-	468.00	4,680.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	364	3,640	710.00	7,100.00
Total-Labor							$2,508.00	$25,080.00
TOTAL							$7,302.73	$73,027.30

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 100 ppf Section 11.5"x6.5" Cu Yds Concrete 0.77 Strand 1-$1\frac{1}{4}$"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	767	3,835	$1725.00	$5625.00	$ 17.25	$ 172.50
Strand							10,890.00	108,900.00
Bearing Assembly							279.00	2,760.00
Ready Mix Concrete	Cu. Yd.	$11.15	77	770			859.00	8,590.00
Total-Mat'l.							$12,045.25	$120,422.50
ITEM Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Carpenters	Hour	$3.09	3.5	.767			$ 828.00	$ 8,280.00
Common Labor	Hour	$1.90	2	.767			291.50	2,915.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,282.00	$ 12,820.00
TOTAL							$13,327.25	$133,242.00

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 200 psf Section 10" x 21" Cu Yds Concrete 2.16 Lbs Reinforced Steel 420

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$.296	173.2	346.4	\$51.30	\$102.60	\$ 25.65	\$ 102.60
Reinforcing Bars	Pound	\$.0879	420	4,200	-	-	36.95	369.50
Ready Mix Concrete	Cu. Yd.	\$11.15	2.16	21.6	-	-	24.10	241.00
Total-Mat'l.							\$ 86.70	\$ 713.10
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	\$3.09	1.735	1	10	\$ 48.20	\$ 482.00
Common Labor	Hour	6.5	\$1.90	1.735	1	10	21.40	214.00
Total-Labor							\$ 69.60	\$ 696.00
TOTAL							\$156.30	\$1,409.10

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 200 psf Section 14.5"x8" Cu Yds Concrete 1.20 Strand 1-$\frac{3}{8}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	123.4	246.8	$36.60	$73.20	$ 18.30	$ 73.20
Strand							128.80	1,288.00
Bearing Assembly							3.18	31.80
Ready Mix Concrete	Cu. Yd.	$11.15	1.20	12.0			13.39	133.90
Total-Mat'l.							$163.67	$1,526.90
ITEM / Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Carpenter	Hour	9	$3.09	1.234	1	10	$ 34.30	$ 343.00
Common Labor	Hour	6.5	$1.90	1.234	1	10	15.23	152.30
Total-Labor							$ 49.53	$ 495.30
TOTAL							$213.20	$2,022.20

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 200 ppf Section 10" x 21" Cu Yds Concrete 2.16 Lbs Reinforced Steel 420

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,400	7,000	$3150.00	$15750.00	$ 31.50	$ 315.00
Reinforcing Bars	Pound	$.0844	42,000	420,000	-	-	3,545.00	35,450.00
Ready Mix Concrete	Cu. Yd.	$11.15	216	2,160	-	-	2,408.00	24,080.00
Total-Mat'l.							$5,984.50	$59,845.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	1.4	-	-	$1,512.00	$15,120.00
Common Labor	Hour	$1.90	2	1.4	-	-	532.50	5,325.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	420.0	4,200.0	819.00	8,190.00
Total-Labor							$2,863.50	$28,635.00
TOTAL							$8,848.00	$88,480.00

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 200 ppf Section 14.5"x8" Cu Yds Concrete 1.20 Strand 1-1 3/8"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	967	4,835	$2175.00	$10875.	$ 21.75	$ 217.50
Strand							12,880.00	128,800.00
Bearing Assembly							318.00	3,150.00
Ready Mix Concrete	Cu. Yd.	$11.15	120	1,200			1,339.00	13,390.00
Total-Mat'l.							$14,558.75	$145,557.50
ITEM	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Labor								
Carpenters	Hour	$3.09	3.5	.967			$ 1,045.00	$ 10,450.00
Common Labor	Hour	$1.90	2	.967			367.50	3,675.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,575.00	$ 15,750.00
TOTAL							$16,133.75	$161,307.50

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 300 psf Section 10"x23.5" Cu Yds Concrete 2.42 Lbs Reinforced Steel 546

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	190	380	$56.25	$112.50	$ 28.13	$ 112.50
Reinforcing Bars	Pound	$.0879	546	5,460	-	-	48.00	480.00
Ready Mix Concrete	Cu. Yd.	$11.15	2.42	24.2	-	-	27.00	270.00
Total-Mat'l.							$103.13	$ 862.50
ITEM	**Unit**	**No. Units per 100 S.F.C.S. per Beam**	**Cost per Labor Unit**	**No. of 100 S.F.C.S. per Beam**	**No. Assemblies & Disassemblies 1 Form**	**No. Assemblies & Disassemblies 2 Forms**		
Labor								
Carpenter	Hour	9	$3.09	1.898	1	10	$ 52.75	$ 527.50
Common Labor	Hour	6.5	$1.90	1.898	1	10	23.40	234.00
Total-Labor							$ 76.15	$ 761.50
TOTAL							$179.28	$1,624.00

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 300 ppf Section 16.5"x9" Cu Yds Concrete 1.53 Strand 1-1 9/16"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Flywood Forms	S.F.C.S.	$.296	140.0	280.0	$41.40	$82.80	$ 20.70	$ 82.80
Strand							163.20	1,632.00
Bearing Assembly							3.49	34.90
Ready Mix Concrete	Cu. Yd.	$11.15	1.53	15.3			17.09	170.90
Total-Mat'l.							$204.48	$ 1,920.60
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.40	1	10	$ 38.90	$ 389.00
Common Labor	Hour	6.5	$1.90	1.40	1	10	17.30	173.00
Total-Labor							$ 56.20	$ 562.00
TOTAL							$260.68	$2,482.60

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 300 ppf Section 10"x23.5" Cu Yds Concrete 2.42 Lbs Reinforced Steel 546

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,568	7,840	$3525.00	$17625.00	$ 35.25	$ 352.50
Reinforcing Bars	Pound	$.0844	54,600	546,000	-	-	4,610.00	46,100.00
Ready Mix Concrete	Cu. Yd.	$11.15	242	2,420	-	-	2,699.00	26,990.00
Total-Mat'l.							$ 7,344.25	$ 73,442.50
ITEM Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Carpenters	Hour	$3.09	3.5	1.568	-	-	$ 1,693.00	$ 16,930.00
Common Labor	Hour	1.90	2	1.568	-	-	595.00	5,950.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	546	5,460	1,064.00	10,640.00
Total-Labor							$ 3,352.00	$ 33,520.00
TOTAL							$10,696.25	$106,962.50

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 300 psf Section 16.5"x9" Cu Yds Concrete 1.53 Strand 1-1 9/16"

ITEM — Material	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,099	5,495	$2470.00	$12350.	$ 24.70	$ 247.00
Strand							16,320.00	163,200.00
Bearing Assembly							349.00	3,460.00
Ready Mix Concrete	Cu. Yd.	$11.15	153	1,530			1,709.00	17,090.00
Total-Mat'l.							$18,402.70	$183,997.00
ITEM — Labor	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Carpenters	Hour	$3.39	3.5	1.099			$ 1,186.00	$ 11,860.00
Common Labor	Hour	$1.90	2	1.099			417.00	4,170.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,765.50	$ 17,655.00
TOTAL							$20,168.20	$201,652.00

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 400 psf Section 11.5"x26" Cu Yds Concrete 3.075 Lbs Reinforced Steel 671

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTED (1 Form) 1 Beam	COST ALLOTED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	211.6	423.2	$62.60	$125.20	$ 31.30	$ 125.20
Reinforcing Bars	Pound	$.0879	671	6,710	-	-	59.00	590.00
Ready Mix Concrete	Cu. Yd.	$11.15	3.075	30.75	-	-	34.25	342.50
Total-Mat'l.							$124.55	$1,057.70
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	2.116	1	10	$ 58.90	$ 589.00
Common Labor	Hour	6.5	$1.90	2.116	1	10	26.15	261.50
Total-Labor							$ 85.05	$ 850.50
TOTAL							$209.60	$1,908.20

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 400 ppf Section 18.5"x9.5" Cu Yds Concrete 1.80 Strand # 1-1 5/8"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.296	155.0	310.0	$45.80	$91.60	$ 22.90	$ 91.60
Strand							173.70	1,737.00
Bearing Assembly							4.59	45.90
Ready Mix Concrete	Cu. Yd.	$11.15	1.80	18.0			20.10	201.00
Total-Mat'l.							$221.29	$2,075.50
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.55	1	10	$ 43.10	$ 431.00
Common Labor	Hour	6.5	$1.90	1.55	1	10	19.12	191.20
Total-Labor							$ 62.22	$ 622.20
TOTAL							$283.51	$2,697.70

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 400 ppf Section 11.5"x26" Cu Yds Concrete 3.075 Lbs Reinforced Steel 671

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,734	8,670	$3900.00	$19500.00	$ 39.00	$ 390.00
Reinforcing Bars	Pound	$.0844	67,100	671,000	-	-	5,665.00	56,650.00
Ready Mix Concrete	Cu. Yd.	$11.15	307.5	3,075	-	-	3,430.00	34,300.00
Total-Mat'l.							$ 9,134.00	$ 91,340.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	$3.09	3.5	1.734	-	-	$ 1,873.00	$ 18,730.00
Common Labor	Hour	1.90	2	1.734	-	-	659.00	6,590.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	671	6,710	1,309.00	13,090.00
Total-Labor							$ 3,841.00	$ 38,410.00
TOTAL							$12,975.00	$129,750.00

COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 400 psf Section 18.5"x[illegible].5" Cu Yds Concrete 1.80 Strand 1-1 5/8"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST 10 Forms	TOTAL FORM COST 50 Forms	COST ALLOWED (10 Forms) 100 Beams	COST ALLOWED (50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,235	6,175	$2760.00	$13900.	$ 27.80	$ 278.00
Strand							17,370.00	173,700.00
Bearing Assembly							459.00	4,560.00
Ready Mix Concrete	Cu. Yd.	$11.15	180	1,800			2,010.00	20,100.00
Total-Mat'l.							$19,866.80	$198,638.00
ITEM	**Unit**	**Unit Cost**	**No. Units per 100 S.F.C.S.**	**No. of 100 S.F.C.S. per Beam**	**No. Units per Beam**			
Labor								
Carpenters	Hour	$3.09	3.5	1.235			$ 1,334.00	$ 13,340.00
Common Labor	Hour	$1.90	2	1.235			469.00	4,690.00
Structural Iron Worker	Hour	$3.25			1/2		162.50	1,625.00
Total-Labor							$ 1,965.50	$ 19,655.00
TOTAL							$21,832.30	$218,293.00

COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 500 psf Section 13" x 25" Cu Yds Concrete 3.74 Lbs Reinforced Steel 728

ITEM — Material	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Plywood Forms	S.F.C.S.	$.296	230	460	$68.10	$136.20	$ 34.05	$ 136.20
Reinforcing Bars	Pound	$.0879	728	7,280	-	-	64.05	640.50
Ready Mix Concrete	Cu. Yd.	$11.15	3.74	37.4	-	-	41.70	417.00
Total-Mat'l.							$139.80	$1,193.70

ITEM — Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies — 1 Form	No. Assemblies & Disassemblies — 2 Forms	COST ALLOTTED (1 Form) 1 Beam	COST ALLOTTED (2 Forms) 10 Beams
Carpenter	Hour	9	$3.09	2.298	1	10	$ 63.80	$ 638.00
Common Labor	Hour	6.5	$1.90	2.298	1	10	28.40	284.00
Total-Labor							$ 92.20	$ 922.00
TOTAL							$232.00	$2,115.70

COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 500 ppf Section 20"x10" Cu Yds Concrete 2.06 Strand 2-$\frac{1}{4}$"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST (1 Form) 1 Beam	COST (2 Forms) 10 Beams	COST ALLOWED (1 Form) 1 Beam	COST ALLOWED (2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	$.295	166.7	333.3	$49.30	$98.60	$ 24.65	$ 98.60
Strand							217.80	2,178.00
Bearing Assembly							7.41	74.10
Ready Mix Concrete	Cu. Yd.	$11.15	2.06	20.6			22.98	229.80
Total-Mat'l.							$272.84	$2,580.50
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies 1 Form	No. Assemblies & Disassemblies 2 Forms		
Labor								
Carpenter	Hour	9	$3.09	1.667	1	10	$ 46.30	$ 463.00
Common Labor	Hour	6.5	$1.90	1.667	1	10	20.55	205.50
Total-Labor							$ 66.85	$ 668.50
TOTAL							$339.69	$3,249.00

COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

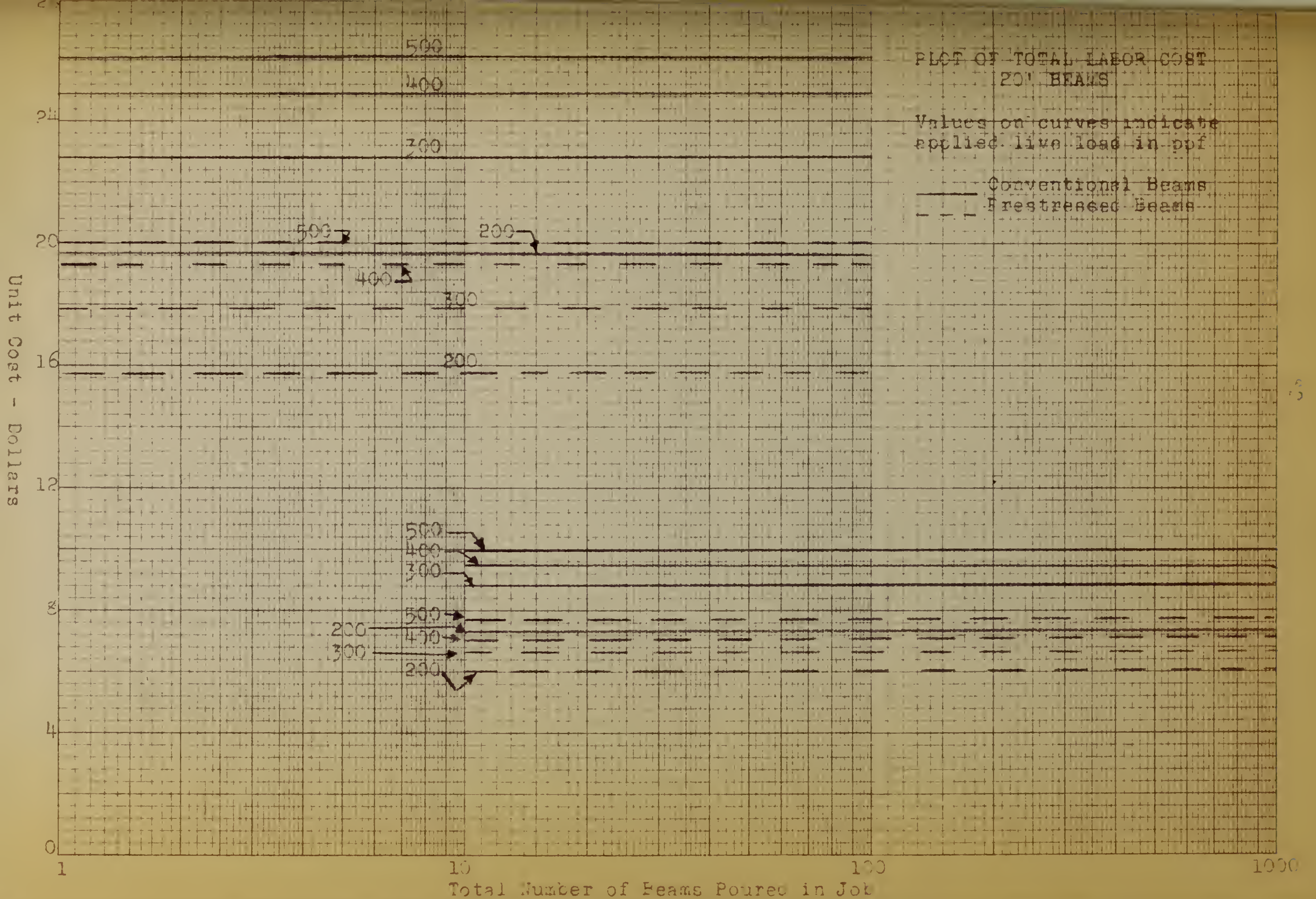
Length 40' Load 500 psf Section 13" x 28" Cu Yds Concrete 3.74 Lbs Reinforced Steel 728

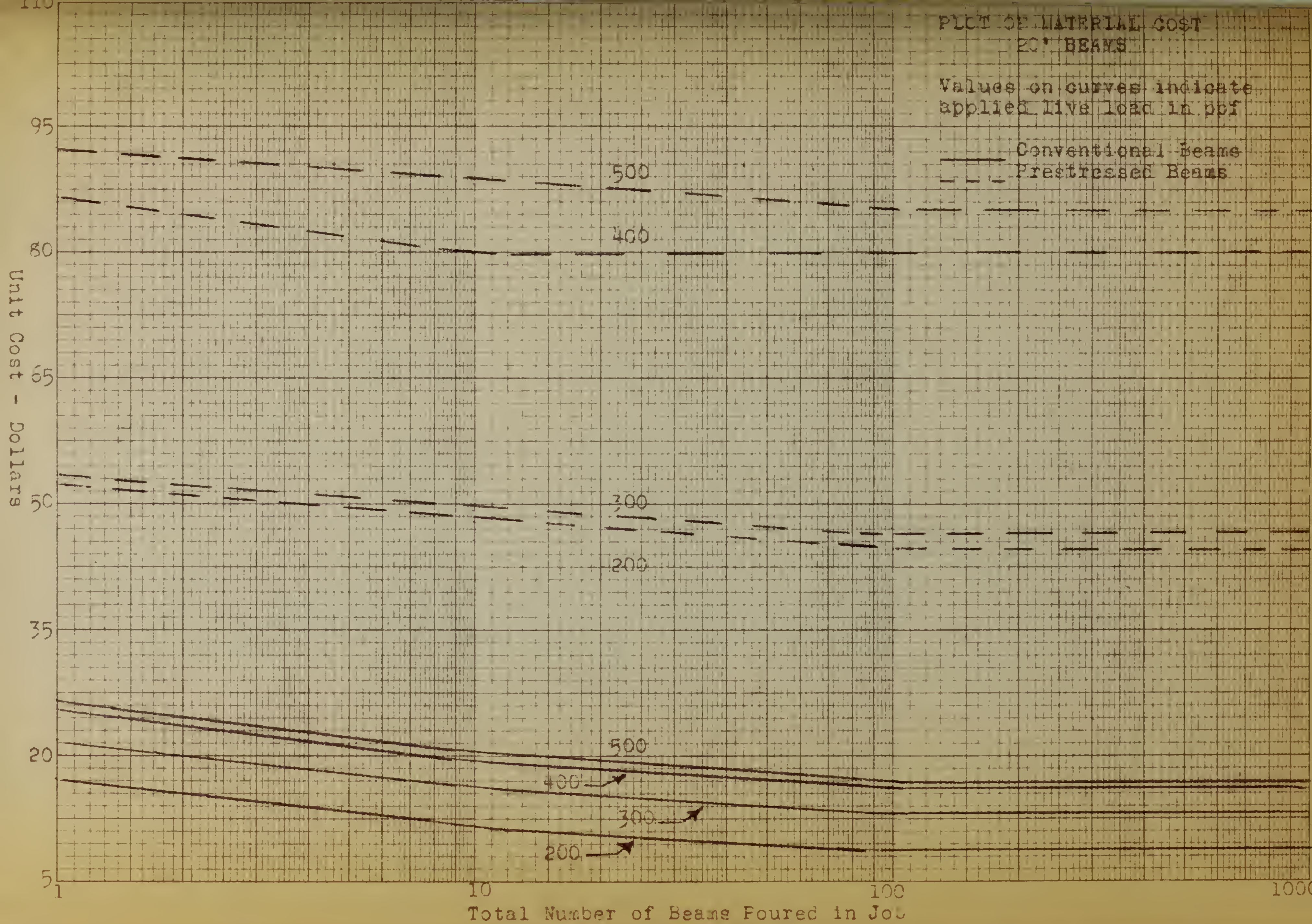
ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOTTED	
Material					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,867	9,335	$4,200	$21,000	$ 42.00	$ 420.00
Reinforcing Bars	Pound	$.0844	72,800	728,000	-	-	6,150.00	61,500.00
Ready Mix Concrete	Cu. Yd.	$11.15	374	3,740	-	-	4,170.00	41,700.00
Total-Mat'l.							$10,362.00	$103,620.00
ITEM Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Carpenters	Hour	$3.09	3.5	1.867	-	-	$ 2,015.00	$ 20,150.00
Common Labor	Hour	$1.90	2	1.867	-	-	708.00	7,080.00
Structural Iron Worker	Cwt. of Steel	$1.95	-	-	728	7,280	1,420.00	14,200.00
Total-Labor							$ 4,143.00	$ 41,430.00
TOTAL							$14,505.00	$145,050.00

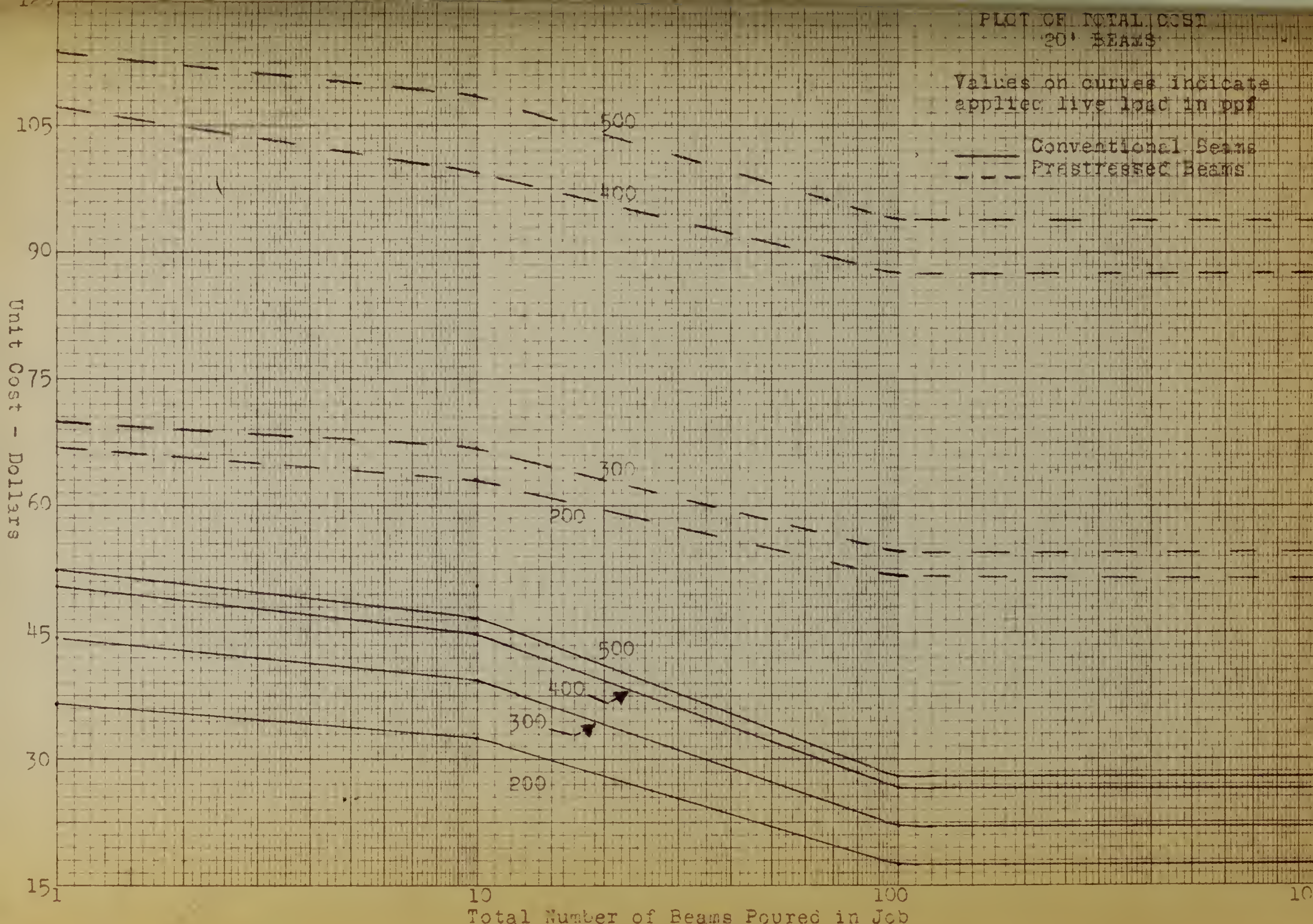
COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

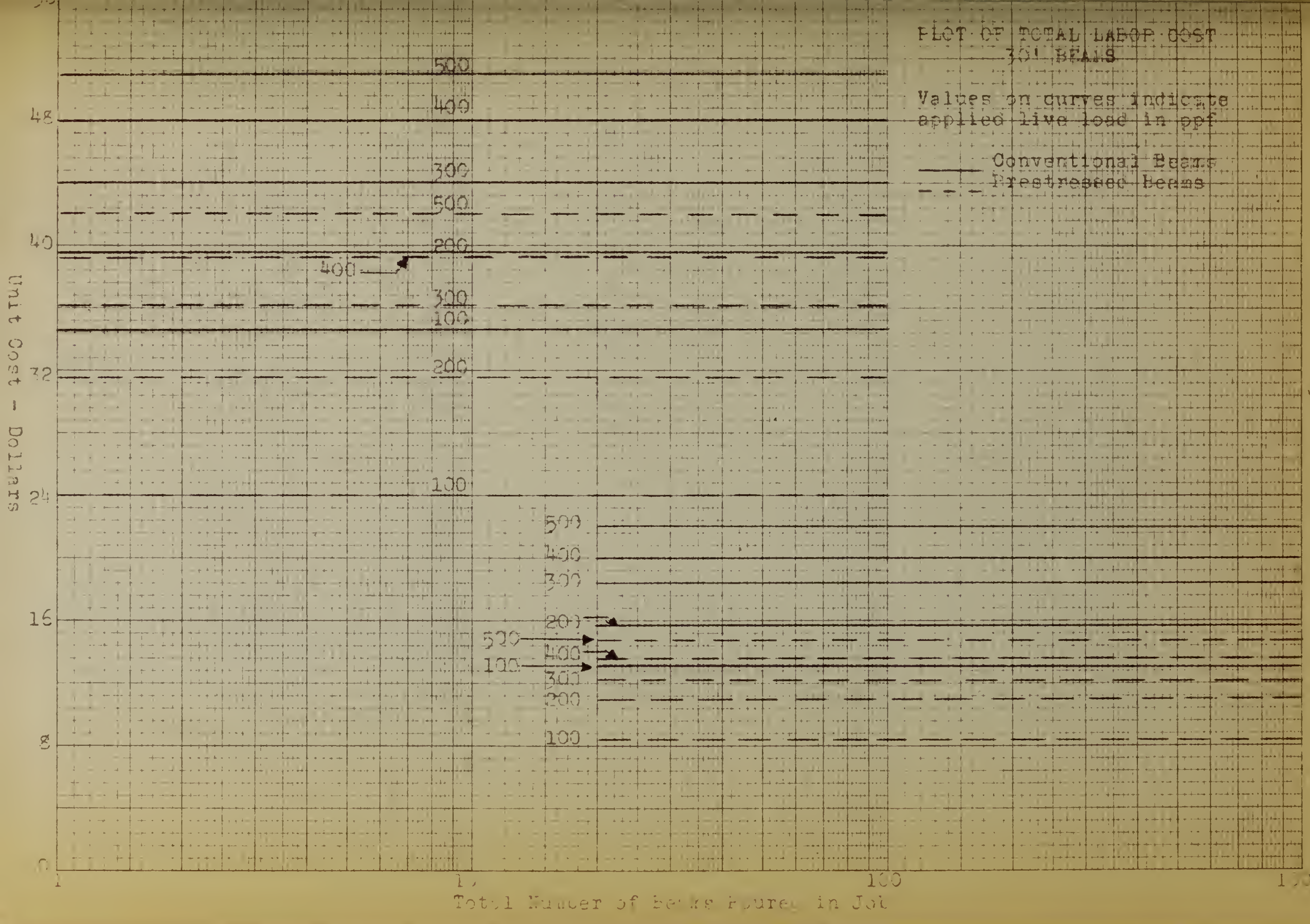
Length 40' Load 500 psf Section 20" x 10" Cu Yds Concrete 2.06 Strand 2-1¼"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	$2.25	1,334	6,670	$3000.00	$15,000.	$ 30.00	$ 300.00
Strand							21,760.00	217,600.00
Bearing Assembly							741.00	7,380.00
Ready Mix Concrete	Cu. Yd.	$11.15	206	2,060			2,298.00	22,980.00
Total-Mat'l.							$24,849.00	$248,460.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	$3.00	3.5	1.334			$ 1,440.00	$ 14,400.00
Common Labor	Hour	$1.90	2	1.334			507.00	5,070.00
Structural Iron Worker	Hour	$3.25			1		325.00	3,250.00
Total-Labor							$ 2,272.00	$ 22,720.00
TOTAL							$27,121.00	$271,180.00

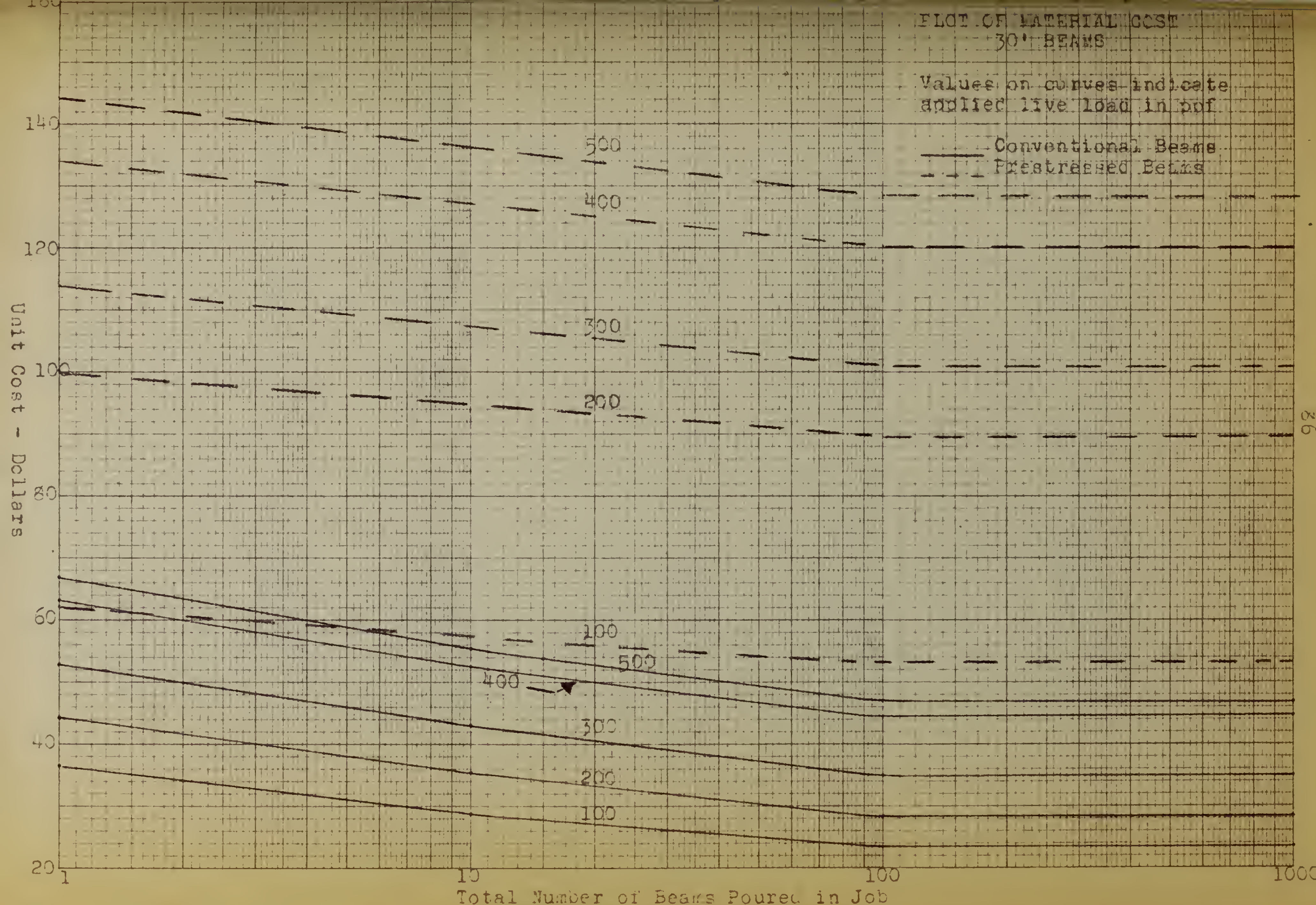

PLOT OF TOTAL LABOR COST
20' BEAMS
Values on curves indicate applied live load in ppf
Conventional Beams
Prestressed Beams
500
400
300
200
Unit Cost - Dollars
Total Number of Beams Poured in Job
0
4
8
12
16
20
24
1
10
100
1000

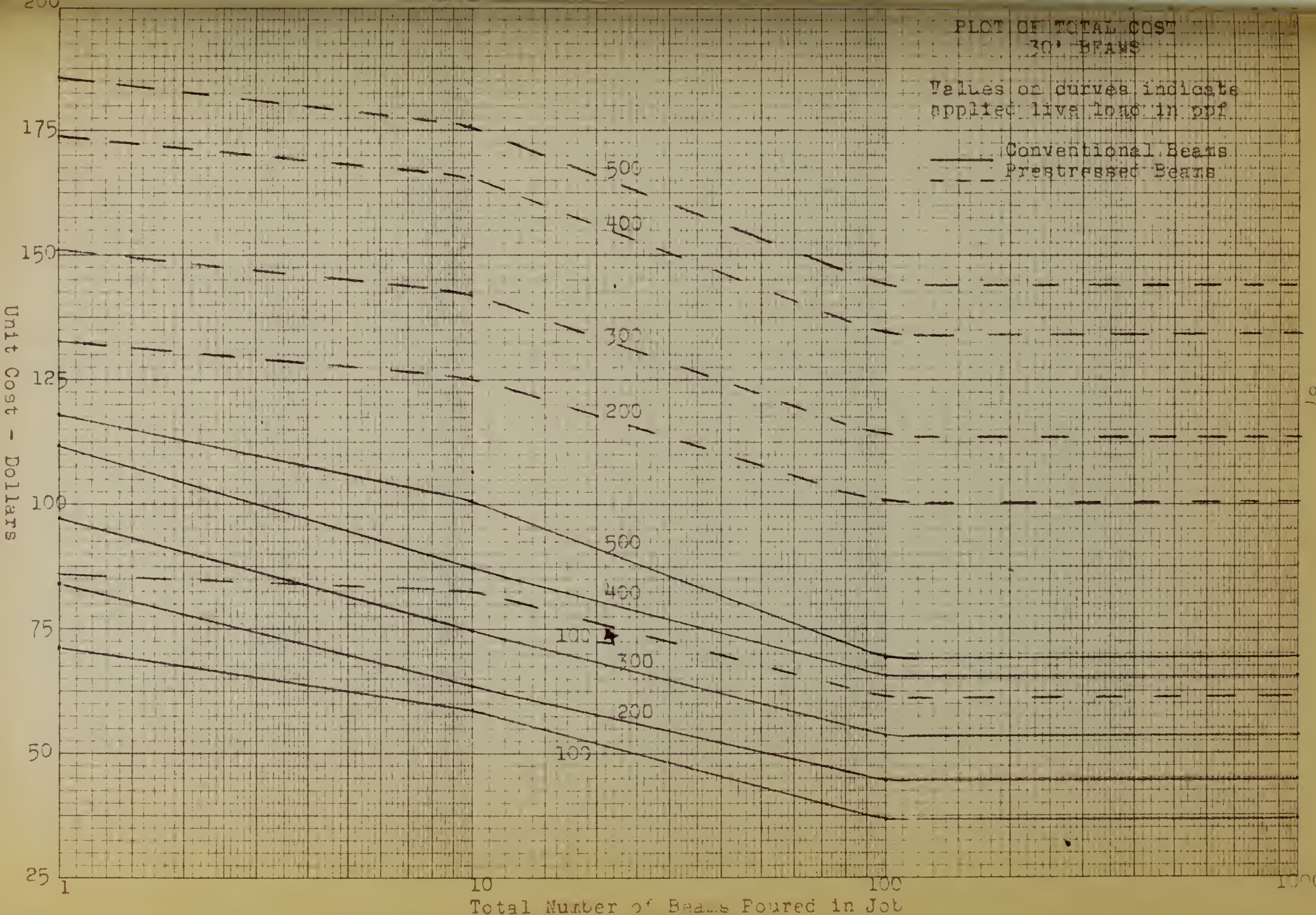

PLOT OF MATERIAL COST
20" BEAMS
Values on curves indicate
applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
500
400
300
200
110
95
80
65
50
35
20
5
Unit Cost - Dollars
1
10
100
1000
Total Number of Beams Poured in Job


PLOT OF TOTAL COST
20' BEAMS
Values on curves indicate
applied live load in ppf
Conventional Beams
Prestressed Beams
500
400
300
200
500
400
300
200
105
90
75
60
45
30
15
Unit Cost - Dollars
1
10
100
1000
Total Number of Beams Poured in Job

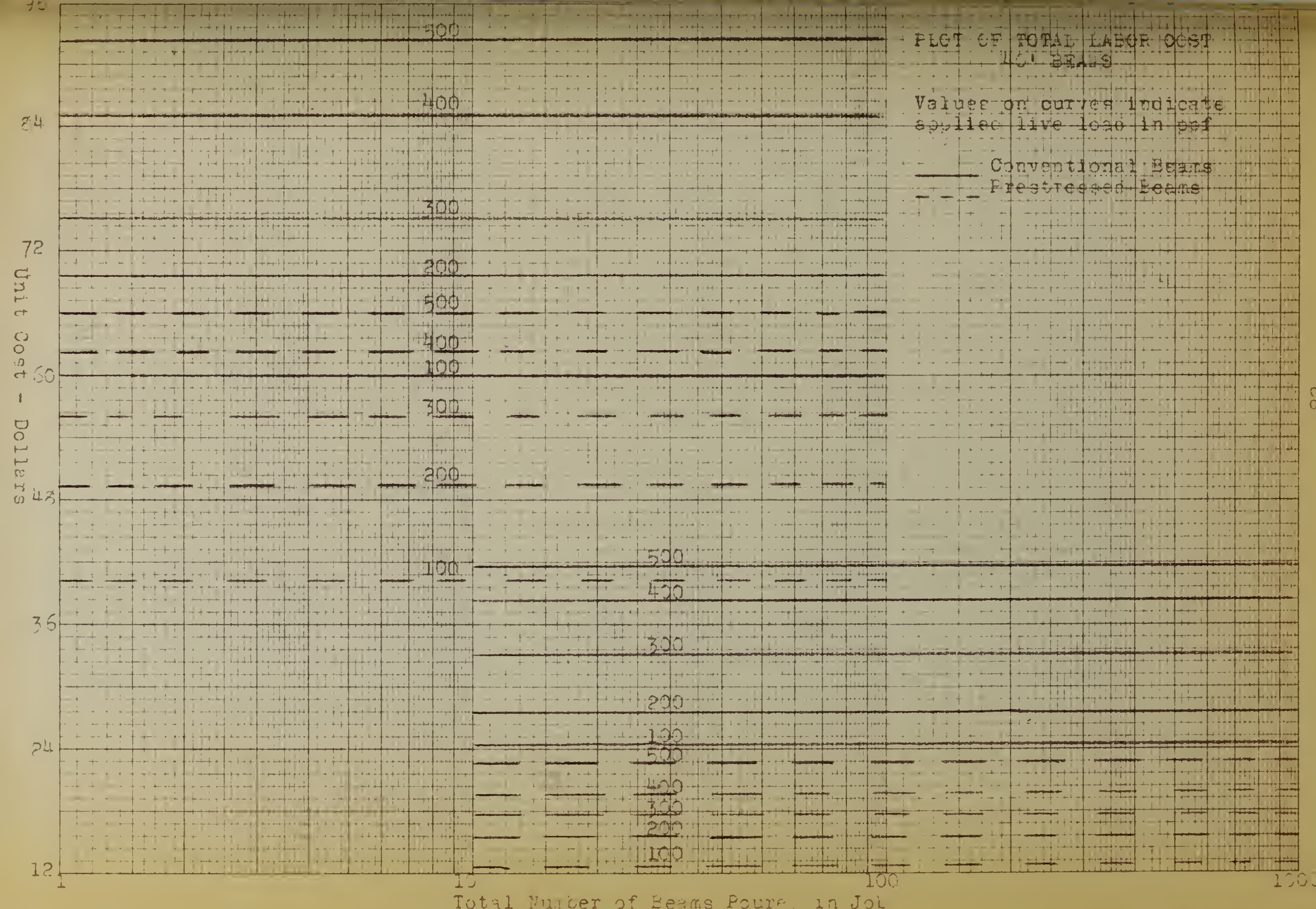


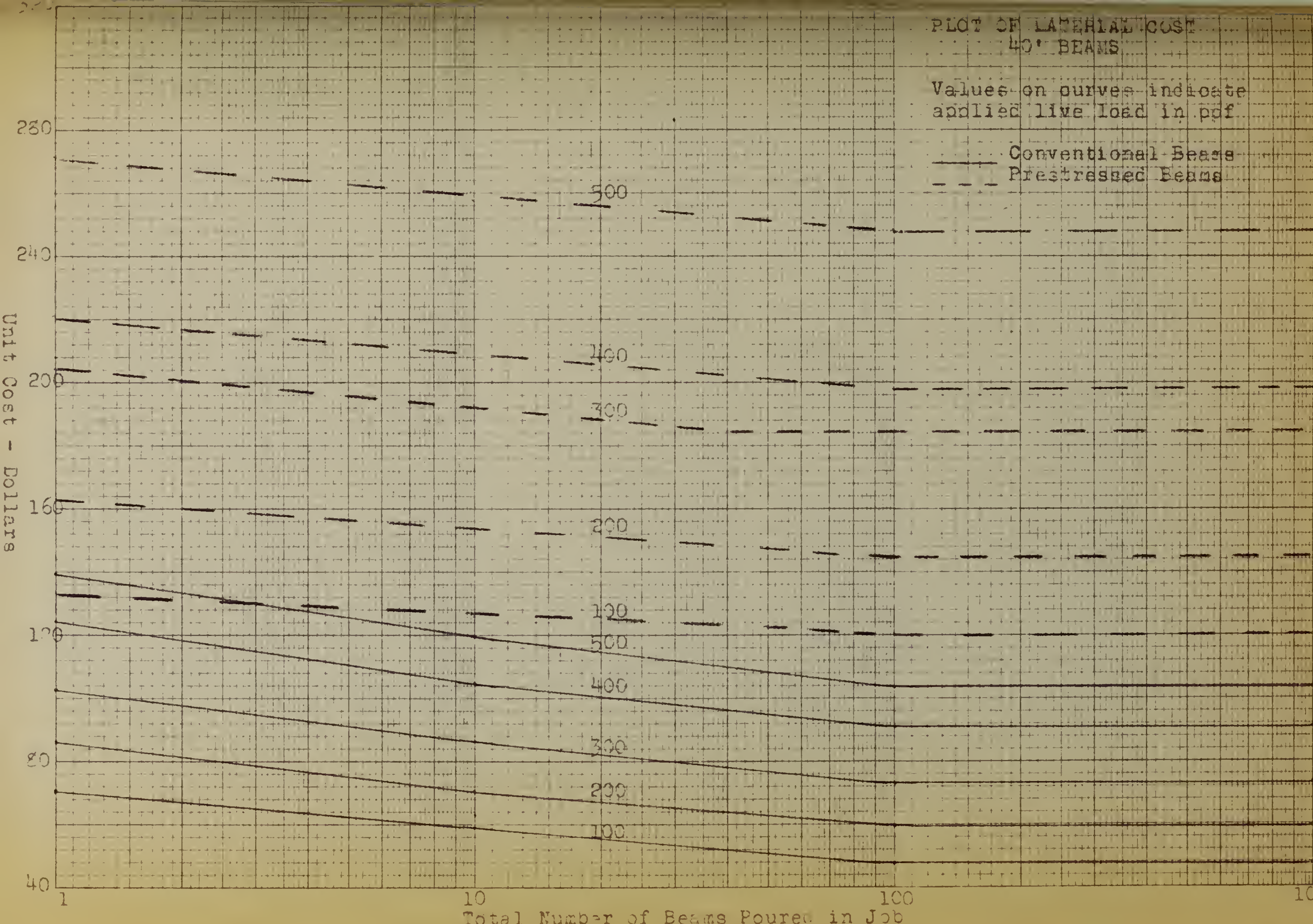
PLOT OF TOTAL LABOR COST
30' BEAMS
Values on curves indicate applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
100
0
8
16
24
32
40
48
1
10
100
1000
Unit Cost - Dollars
Total Number of Beams Poured in Job

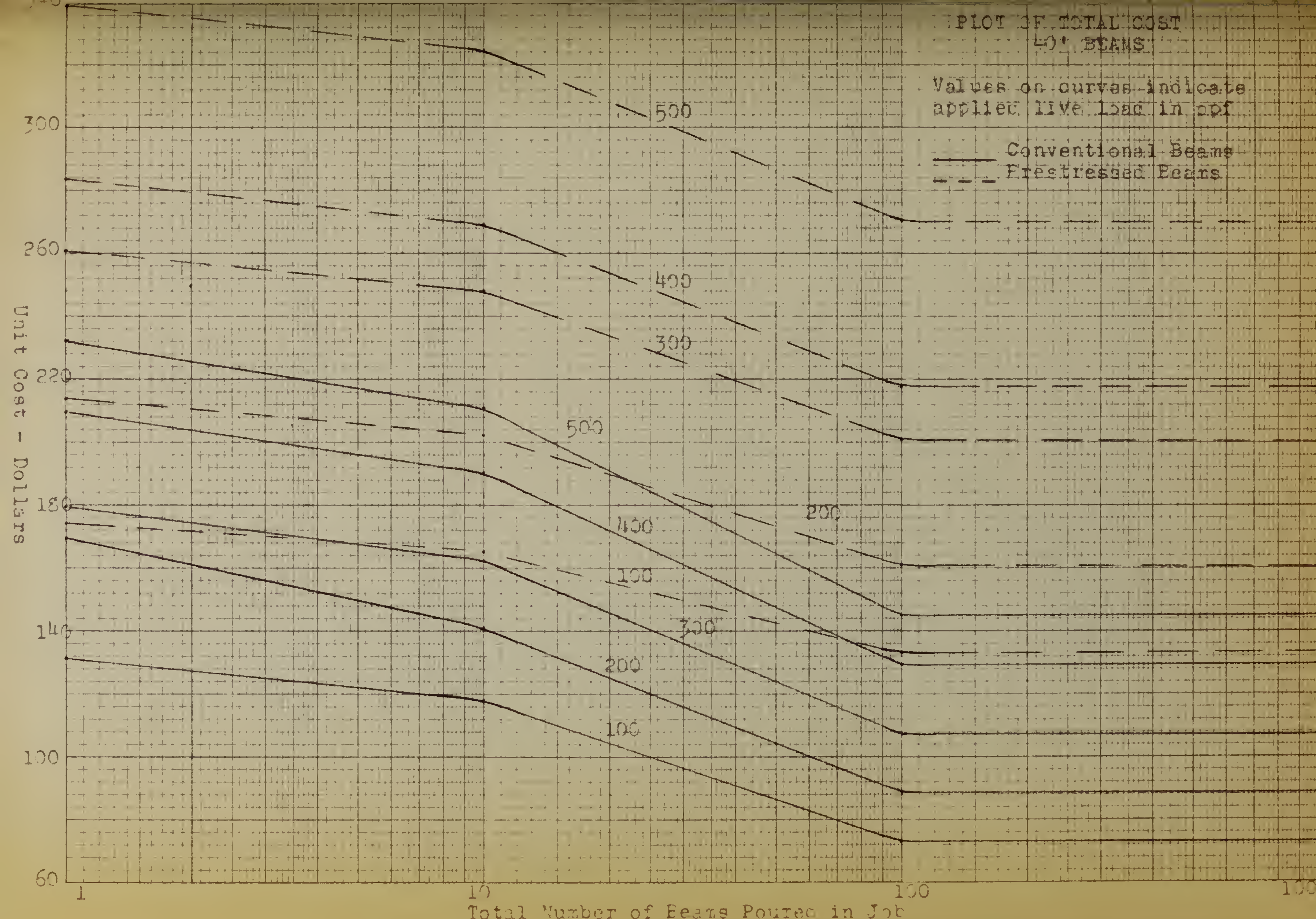

PLOT OF MATERIAL COST
30' BEAMS
Values on curves indicate
applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
100
500
400
300
200
100
140
120
100
80
60
40
20
1
10
100
1000
Unit Cost - Dollars
Total Number of Beams Poured in Job

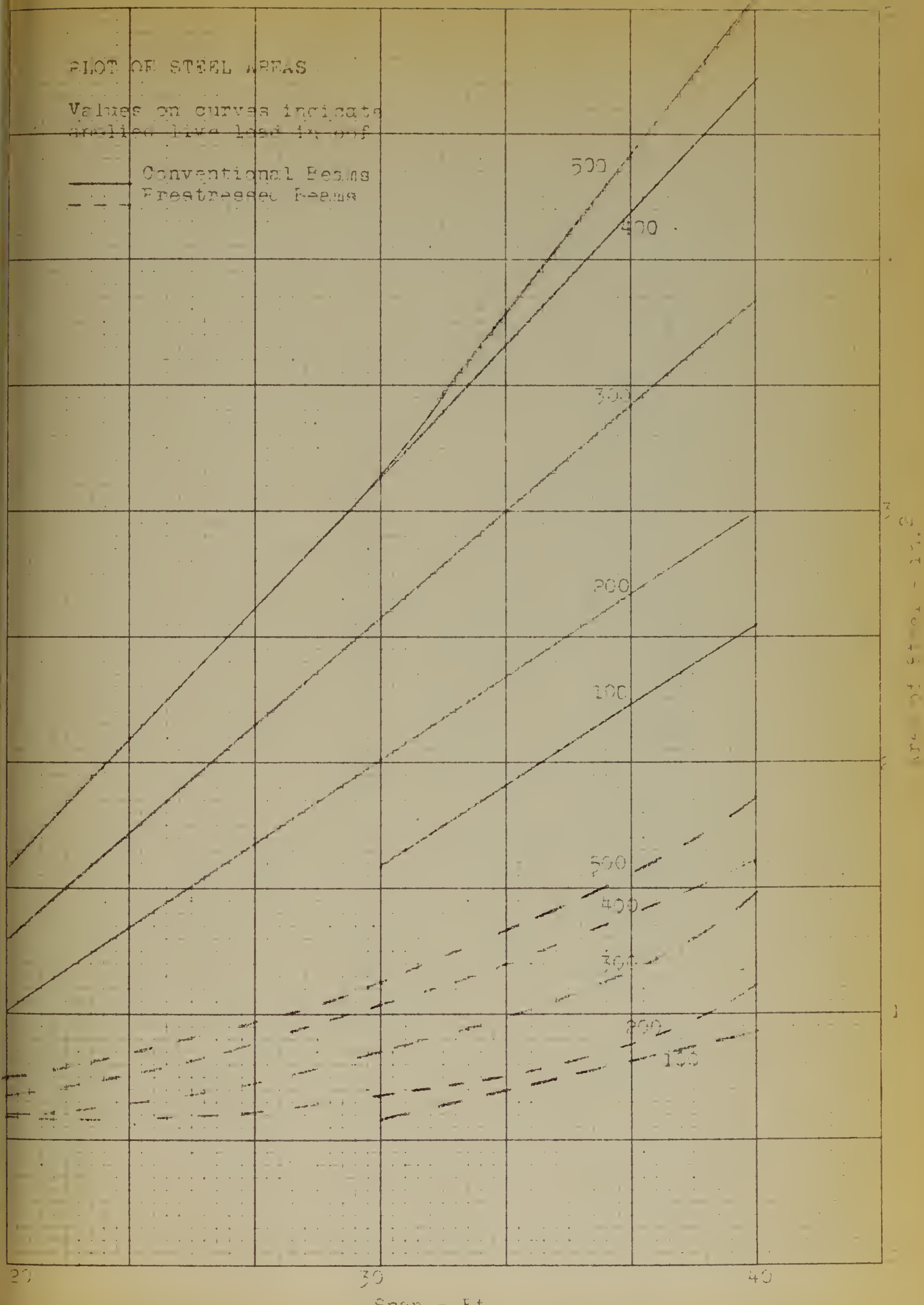


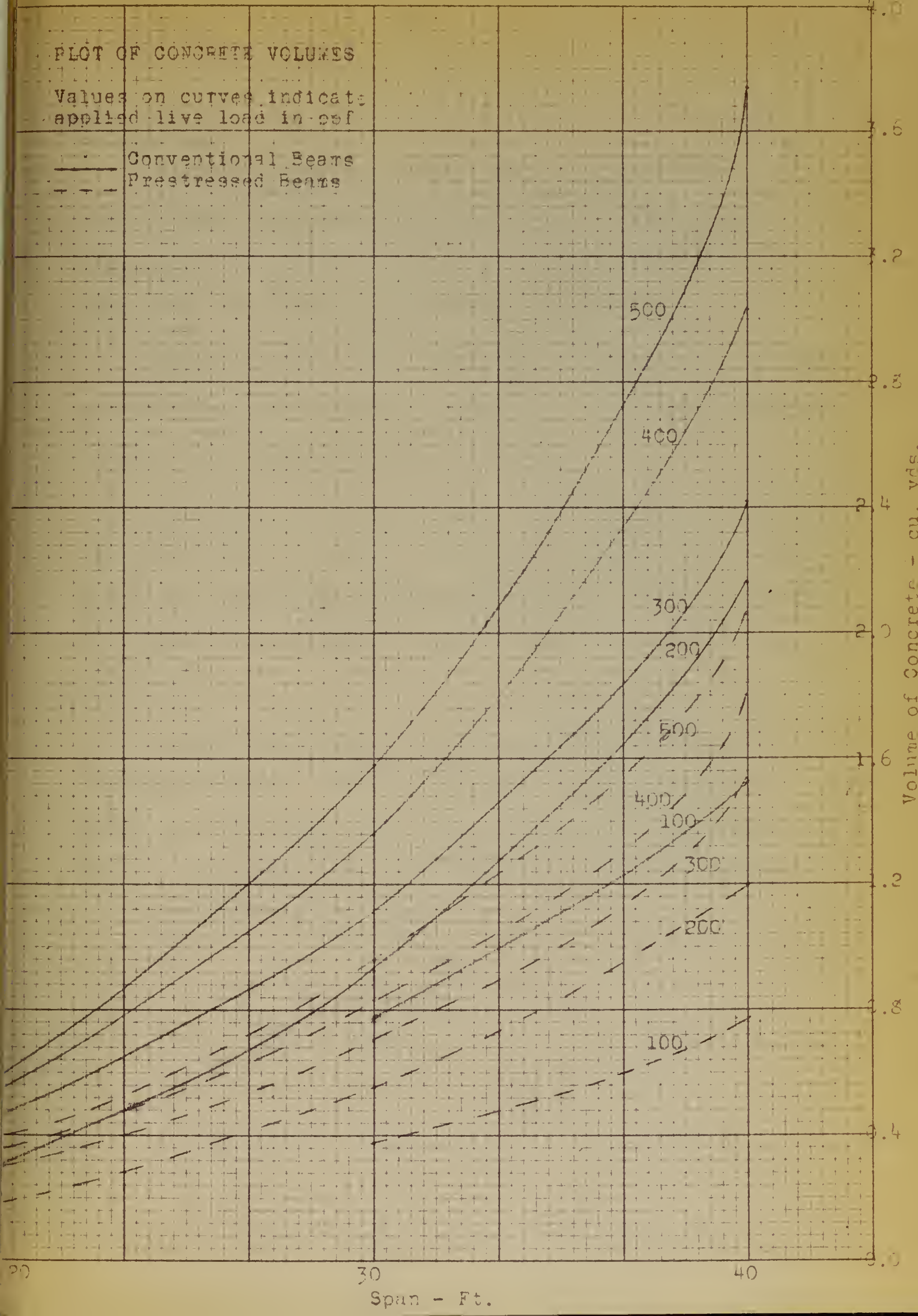
PLOT OF TOTAL COST
30' BEAMS
Values on curves indicate applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
500
400
100
300
200
100
Unit Cost - Dollars
200
175
150
125
100
75
50
25
1
10
100
1000
Total Number of Beams Poured in Job


PLOT OF TOTAL LABOR COST
40' BEAMS
Values on curves indicate
applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
500
400
100
300
200
100
500
400
300
200
100
500
400
300
200
100
84
72
60
48
36
24
12
Unit Cost - Dollars
1
10
100
Total Number of Beams Poured in Job


PLOT OF MATERIAL COST
40' BEAMS
Values on curves indicate applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
100
500
400
300
200
100
40
80
120
160
200
240
280
Unit Cost - Dollars
1
10
100
1000
Total Number of Beams Poured in Job


PLOT OF TOTAL COST
40' BEAMS
Values on curves indicate
applied live load in plf
Conventional Beams
Prestressed Beams
500
400
300
500
200
400
100
300
200
100
300
260
220
180
140
100
60
1
10
100
1000
Unit Cost - Dollars
Total Number of Beams Poured in Job


PLOT OF STEEL AREAS
Values on curves indicate applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
100
500
400
300
200
100
20
30
40
1
Span - Ft.


PLOT OF CONCRETE VOLUMES
Values on curves indicate applied live load in psf
Conventional Beams
Prestressed Beams
500
400
300
200
500
400
100
300
200
100
Volume of Concrete - cu. yds.
Span - Ft.

CONCLUSIONS

From the comparison of the fourteen simple beams, conventional reinforced concrete is more economical in total cost. Prestressed concrete is more economical in labor cost and quantities of concrete and steel.

Despite the fact that less steel and concrete were used in the prestressed beams, the total cost was greater because of the cost of the prestressing strand.

Prestressed concrete compares more favorably at 40 feet than at 20 feet. It can be reasonably assumed that it will become more favorable as the spans increase and at some span will become more economical than conventional concrete in total cost.

At this time there is a very small demand for prestressing strands. When this demand has become large enough to allow mass production, the strands will become cheaper and, therefore, prestressed concrete will compare economically at shorter spans.

PART II

COMPARISON OF A SMALL HIGHWAY BRIDGE

A prestressed concrete bridge in Madison County, Tennessee, was chosen for comparison with a conventional design because it was the first prestressed concrete bridge completed in this country.

The prestressed design consists of three simple beam spans supported on timber pile bents. There are two 20 ft. spans and one 30 ft. span. The beams are unique because they are made up of precast concrete blocks with special end blocks for anchoring the prestressing strand. Each 20 ft. span has one strand and each 30 ft. span has two strands. The concrete blocks have three rectangular holes through which the strands are passed (8).

For the details of the fabrication and the placing of the beams on the bents, the following is quoted from Reference 9:

"... All materials used in the beams, including manufactured concrete block, prestressing cable units, terminals and end plates, were delivered at the yard. Blocks were stacked to facilitate fabrication and cut hand carry distance. There were a total of forty-five beams, built by nine men (2 convicts), organized in two crews with one man placing

cables for both crews. Bridge lumber was used to lay eleven beds upon which beams were built. Beams were built in stacks of four beams, one on top of the other. First, the end block was laid on the bed. Next, a standard block was mortared and set in place against the end block. While each block was being placed, others were being mortared and made ready for use. As construction of each beam progressed, cables were threaded. The beam was completed with another end block. End Plates were put on the cable terminals and nuts tightened slightly. Prestressing was not done until after the initial set of the mortar. Each beam was built in the above manner. Prestressing was done with a calibrated hydraulic jack and rig. Each beam was stressed in about five minutes, by three men.

"During, and prior to the construction of the beams, abutments were poured, piling driven and caps placed. Piling and caps were of creosoted timber. The abutments consist of a concrete cap and end wall, supported on creosoted timber caps, driven through the approach fills. The bridge has a length of seventy-feet, consisting of three spans, placed 20 feet, 30 feet and 20 feet.

"After the completion of the beams in the yard, they were transported to the site on trucks and trailers. They were loaded on the trucks with the truck mounted crane.

The trucks used were two single log trailers, with 2 ton tractors and one equipment trailer, or low-boy. Loading and hauling was no problem.

"At the bridge site the beams were unloaded by the truck-crane and placed directly on the supports to avoid excessive handling and save time. The beams were placed against each other to form a solid deck. The spans were erected successively and as the first span was completed, the crane was backed upon it and the second span laid. The third span was placed in the same manner. The only problem arising in this phase was the necessity to move the crane off the bridge beside the transport truck, pick up a beam then move back on the bridge to place the beam. The capacity of the truck-crane would not allow booming around to pick up and place beams. Although this took some time to make these moves, it, at the same time, furnished a good test for the beams, as the rear axle load of the crane was 25,000 lbs., load with a 30' beam. This exceeds the H-15-44 design load, without the concrete deck in place. Of course the deck will distribute live load and increase the capacity of the bridge.

"After placing the beams, forms were placed for the curbs and end walls. A three inch concrete deck reinforced with 6x6x6/6 wire mesh was poured directly on the beams..."

"... Total construction time took seven days and as high-early cement was used in the deck, the bridge was opened to traffic in ten days."

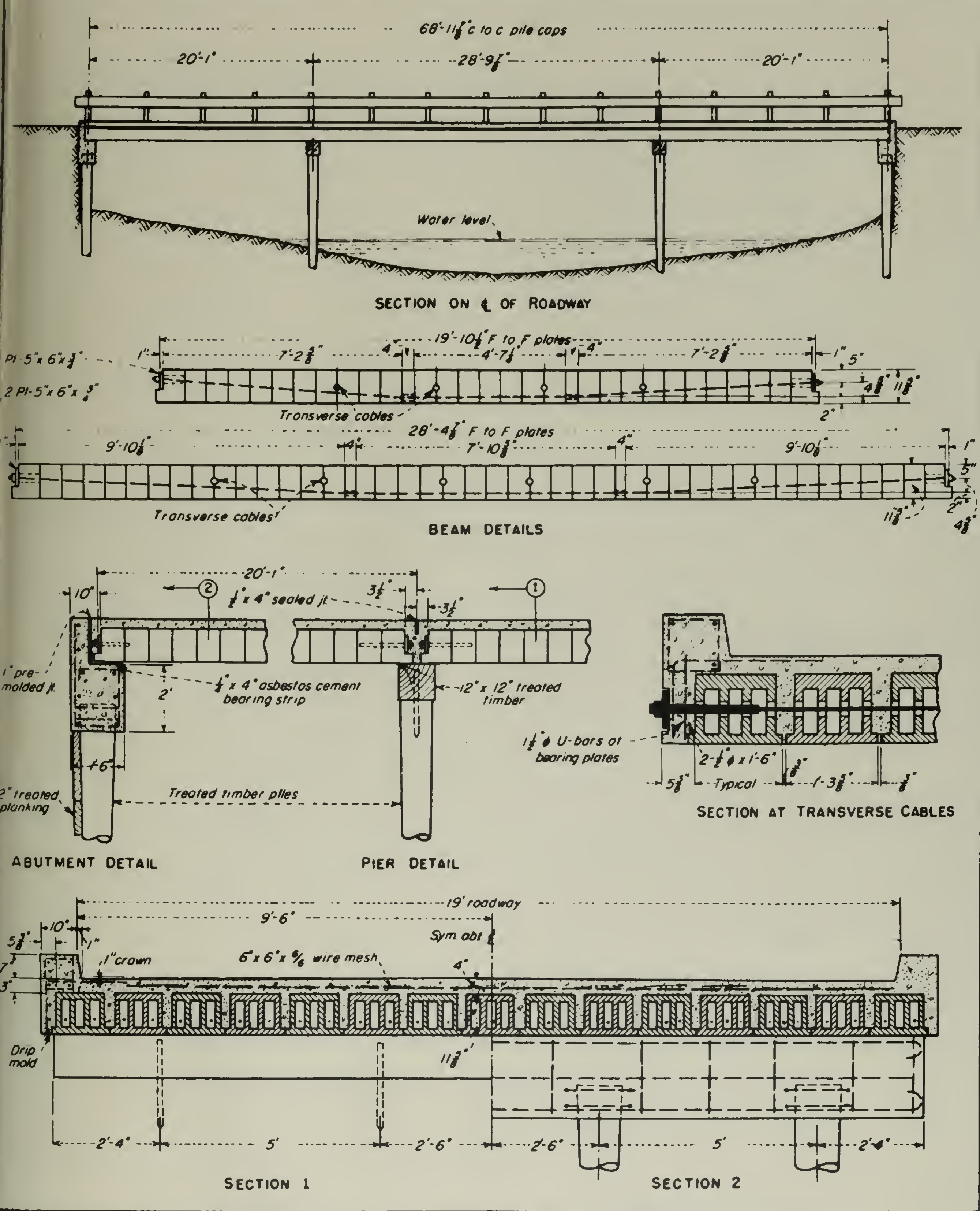
The conventional design is a simple span stringer bridge with a reinforced concrete deck. This design was used by the authors because it is the type of bridge that would have been built on this site if the prestressed design had not been accepted (9). A drawing on page 105 indicates another solution to this design problem. In the design which follows, the AASHO specifications were used.

NCRETE BLOCKS prestressed with a hydraulic jack (left) form beams 20 and 30 ft long. Placed side by side . . .

OCK BEAMS comprise a three-span bridge capable of safely sustaining H 10-44 loading or one H 15 truck.

From Engineering News-Record

January 18, 1951

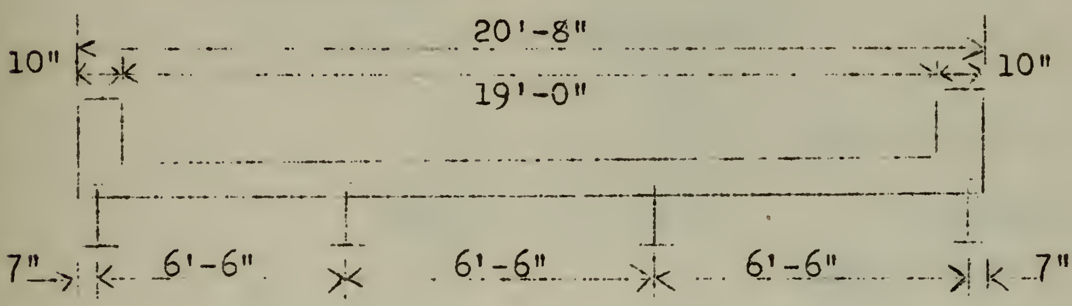


BRIDGE is made up of 45 block beams, 15 per span. Transverse prestressing ties beams together in each span.

From Engineering News-Record

January 18, 1951

Conventional Design Computations



Specifications - AASHO - 1949

Two spans 20'1", one span 28'9$\frac{7}{8}$"

Live load - H10-44 or one H15 truck

Floor Slab Design:

Assume 8" flange

Span = 6'6" - 8" + 4" = 6'2" AASHO 3.3.2

Estimate of DL of span

Assume total t = 7"

structural t = 10"

$w = \frac{10}{12} \times 1 \times 1 \times 150 = 125$ lb/ft

Effective width

$E = .6S + 2.5$ AASHO 3.3.2

$E = .6 \times 6.167 + 2.5 = 3.7 + 2.5 = 6.2$

Bending Moments

$\text{Impact} = \frac{50}{L + 125} = \frac{50}{6.167 + 125} = 38\%$ AASHO 3.2.12

Max. I = 30% ∴ Use 30%

Moments:

Edge Strip

$$\text{Pos. D.L.} = \frac{.125(6.167)^2}{14} = 0.34 \text{ ftK}$$

$$\text{L.L.} = .25 \times \frac{12}{6.2} \times 6.167 = 2.99 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.99 = \underline{0.90 \text{ ftK}}$$

$$\text{Total} = 4.23 \text{ ftK}$$

Edge Strip

$$\text{Neg. D.L.} = \frac{.125(6.167)^2}{10} = 0.48 \text{ ftK}$$

$$\text{L.L.} = .2 \times \frac{12}{6.2} \times 6.167 = 2.39 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.39 = \underline{0.72 \text{ ftK}}$$

$$\text{Total} = 3.59 \text{ ftK}$$

Intermediate Strip

$$\text{Pos. D.L.} = \frac{.1125(6.167)^2}{16} = 0.30 \text{ ftK}$$

$$\text{L.L.} = .2 \times \frac{12}{6.2} \times 6.167 = 2.39 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.39 = \underline{0.72 \text{ ftK}}$$

$$\text{Total} = 3.41 \text{ ftK}$$

$$\text{Neg. D.L.} = \frac{.1125(6.167)^2}{12} = 0.40 \text{ ftK}$$

$$\text{L.L.} = .2 \times \frac{12}{6.2} \times 6.167 = 2.39 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.39 = \underline{0.72 \text{ ftK}}$$

$$\text{Total} = 3.51 \text{ ftK}$$

$\therefore$ Design Moment = 4.23 ftK

f'_c = 3,000 psi AASHO 3.4.12

f_s = 20,000 psi

$n = 10$

$f_c = 1/3f'_c = 1000$ psi $= 1$ Ksi

$r = \frac{f_s}{f_c} = 20$

$k = \frac{n}{n+r} = \frac{10}{30} = .333$

$j = 1 - \frac{k}{3} = 1 - .111 = .889$

$b = 12"$

$M = 1/2 f_c jkbd^2$

$d^2 = \frac{4.23 \times 2 \times 12}{1 \times .889 \times .333 \times 12} = 28.4$

$d = 5.32"$ Use $5\frac{1}{2}"$

$t = 5\frac{1}{2} + 1\frac{1}{2} = 7"$ Assumed 7" OK.

No bond or shear checks required. AASHO 3.3.2(d)

Reinforcement:

Pos. $A_s = \frac{M}{f_s jd} = \frac{4.23 \times 12}{20 \times .881 \times 5.25} = .55$ in.^{2}

Neg. $A_s = \frac{3.59 \times 12}{20 \times .881 \times 5.25} = .465$ in.^{2}

$+A_s$ use $\frac{5}{8}\phi$ @ 12" (straight)

$\frac{5}{8}\phi$ @ 12" (bend up at stringers)

$-A_s$ use $\frac{1}{2}\phi$ @ 12"

Distribution steel

$\% = \frac{100}{\sqrt{S}} = \frac{100}{\sqrt{6.167}} = 40.2\%$

$.402(+A_s) = .402 \times .55 = .222$ in.^{2}

Use $\frac{1}{2}\square$ @ 12"

Quantities:

Concrete:

$$19 \times \frac{10}{12} \times 69 \times \frac{1}{27} + \frac{20}{12} \times \frac{17}{12} \times 69 \times \frac{1}{27} = 46.53 \text{ cu.yd}$$

Steel:

1/2 Φ - 1380 ft = 1155 lb

5/8 Φ - 2818 ft = 2940 lb

1/2 Φ - 1380 ft = $\underline{\ \ 922 \text{ lb}}$
$\qquad\qquad\qquad\qquad\;$ 5017 lb

Stringer Design:

Main span - 28.83'

Dead load moment:

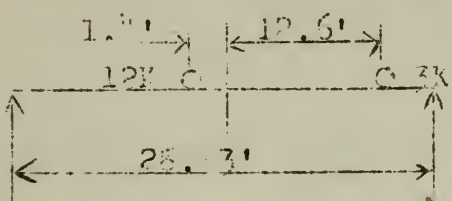
$$\text{DLM concrete slab} = \frac{6.167 \times \frac{10}{12} \times 150(28.83)^2}{8} = 80 \text{ ftK}$$

Assume stringer weight = 82 ppf

$$\text{DLM stringer} = \frac{.082(28.83)^2}{8} = \underline{\ 8.5 \text{ ftK}}$$

Total = 88.5 ftK

Position for max. L.L. moment



$$\text{CG load from front wheel} = \frac{12 \times 14}{15} = 11.2 \text{ ft}$$

$$R_L = \frac{3 \times 1.81 + 12 \times 15.81}{28.83} = \frac{5.4 + 190}{28.83} = 6.78\text{K}$$

LLM = 6.78 x 13 = 87.8 ftK

Overload Provision: AASHO 3.2.4

Increase live load 100%

LLM = 2 x 87.8 = 175.6 ftK

Impact:

$$\% = \frac{50}{L + 125} = \frac{50}{28.83 + 125} = 32.5\%$$

Maximum % = 30 ∴ Use 30% AASHO 3.2.12

I = .3 x LLM

Total Moment:

Normal load

LLM = 87.8 ftK

Impact = 26.3 ftK

DLM = 88.5 ftK

Total = 202.6 ftK

Overload

LLM = 175.6 ftK

Impact = 52.6 ftK

DLM = 88.5 ftK

Total = 316.7 ftK

$$\frac{\text{Overload}}{\text{Normal load}} = \frac{316.7}{202.6} = 1.545$$

$1.545 > 1.5$ ∴ Overload rules.

$$\text{Total design moment} = \frac{316.7}{1.5} = 211 \text{ ftK}$$

f (allowable) = 18 Ksi (L = 0) AASHO 3.4.2

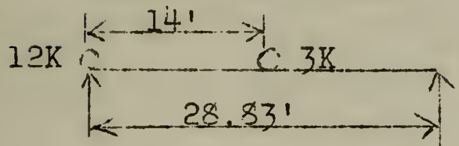
$$S = \frac{M}{f} = \frac{211 \times 12}{18} = 141 \text{ in.}^3$$

Assume 21 WF 73, S = 150.7 in.^{3}

Depth to length ratio $= \dfrac{21}{28.83 \times 12} = .0607$

$.0607 > \dfrac{1}{25}$ $\therefore$ OK AASHO 3.6.11

Maximum Reaction:



$LLR_L = 12 + \dfrac{14.83}{28.83} \times 3 = 13.54$ K

$DLR_L = .073 \times 14.41 + .77 \times 14.41 = 12.15$ K

Impact $R_L = .3 \times 13.54 = \underline{4.07 \text{ K}}$

Total = 29.76 K

Shear on Web:

Actual $= \dfrac{29.76}{21.24 \times .455} = 3.07$ Ksi

$3.07 < 11$ $\therefore$ OK

Stiffeners:

$\dfrac{d}{t} = \dfrac{21.24}{.455} = 46.8$ AASHO 3.6.80

$46.8 < 60$ $\therefore$ OK Stiffeners not required.

The stringers for the two 20 ft. spans were designed as above. The design resulted in four 21 WF 62 stringers per span.

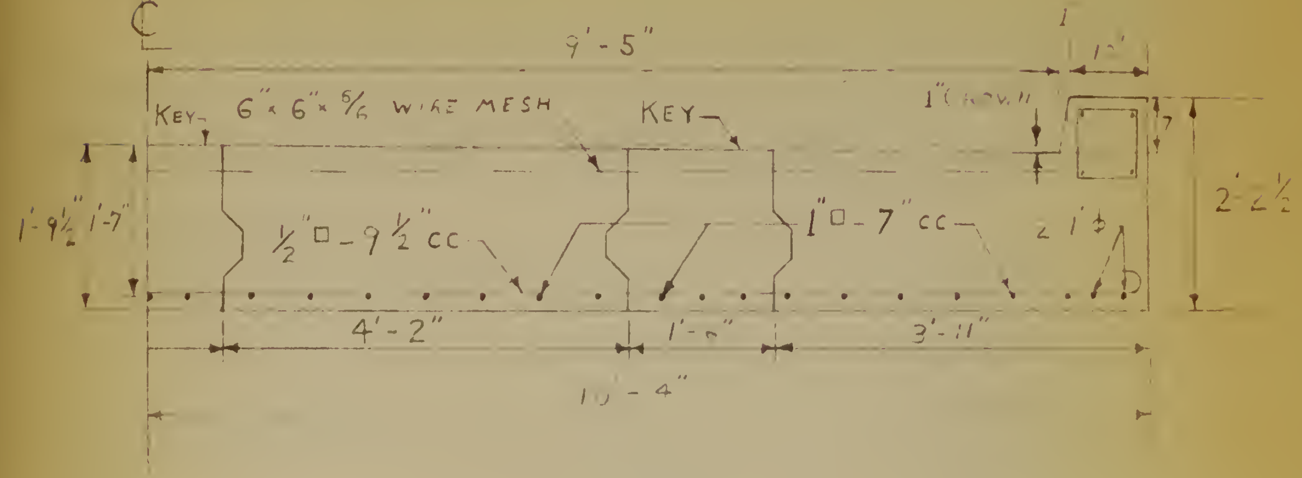
ALTERNATE DESIGN

Another possible solution to the conventional design is to use a flat slab without stringers. This solution was suggested by personnel of the Bridges, Grade Separations and Structures Section, Construction Division, New York Department of Public Works.

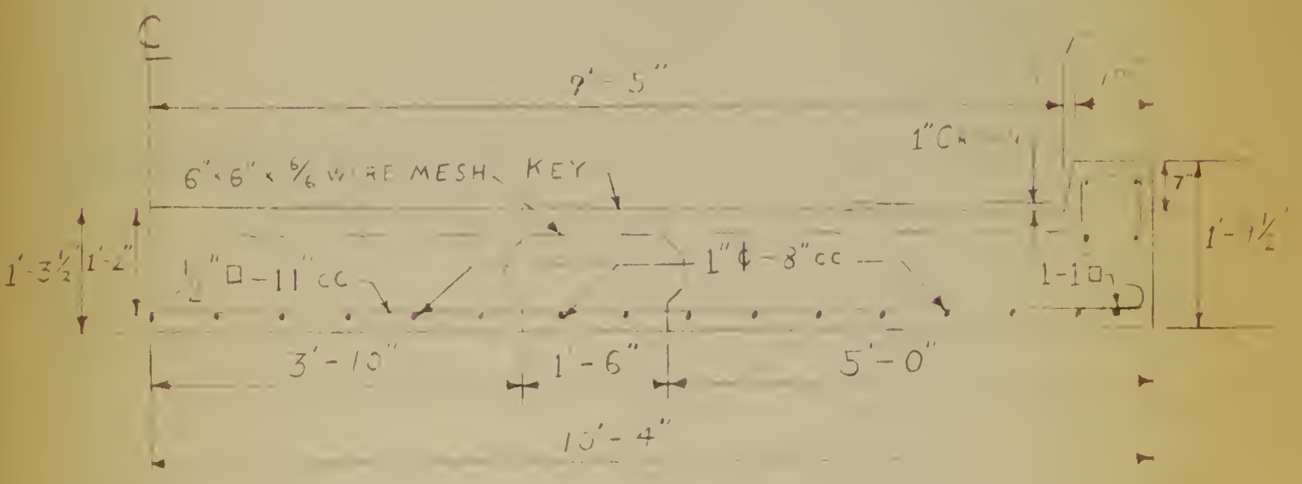
This design was made and the two slab sections on the following page detailed. However, further correspondence with Mr. Rodgers, County Engineer of Madison County, revealed that there was no crane in the immediate locality of sufficient size to place the sections. As it would not be economical to transport such a crane for any considerable distance, a cost estimate for this design was not made.

The proposed construction procedure was to pour the slab sections either in the contractor's yard or adjacent to the bridge site. When at the site they would be placed on the beams by the crane. The keys would then be cast in place, the form work being supported by bolts cast into the slab sections.

Conventional Slab Bridge Details
Alternate Design



Half Cross Section - Center Span



Half Cross Section - Side Span

PRESTRESSED BRIDGE COST

The following breakdown of costs for the prestressed bridge was supplied by the Highway Department of Madison County, Tennessee (10). These costs are for the superstructure only.

Beam Construction:	Labor	$ 429.22
	Materials	1,809.42
Beam Laying:	Labor	234.28
	Equipment	129.01
Forming Deck:	Labor	323.78
	Equipment	36.13
Deck Concrete:	Labor	297.17
	Materials	770.27
	Equipment	24.50
		$4,053.78

CONVENTIONAL BRIDGE COST (For superstructure only)

I. Estimate of Quantities:

Item	Unit	Net	Round
Concrete	Cu yd	46.53	50
Cement	Bbl	61.3	63.0
Gravel	Ton	43.4	45.0
Sand	Ton	32.75	34.0
Structural Steel	Lb	18680	19,000
Reinforcing Steel	Lb	5017	5,500
Forms	BF	3940	4,000

I. Estimate of Quantities (Cont'd.):

Item	Unit	Net	Round
Labor (as taken from Ref. 12):			
Mix and place concrete @ 4 hrs/cu yd	Hr	186.12	200
Place reinforcing @ 16 hrs/ton	Hr	40.1	44
Make up forms @ 6 hrs/100 SFCS	Hr	85.8	90
Erect and remove forms @ 9 hrs/100 SFCS	Hr	129	135
Move forms @ 2 hrs/100 SFCS	Hr	28.6	30

II. Estimate of Costs:

Item	Unit	Quantity	Unit Price	Cost
Cement	Bbl	63	$3.00	$ 189.00
Gravel	Ton	45	2.24	101.00
Sand	Ton	34	1.84	62.50
In place Structural Steel	Lb	19,000	.10	1,900.00
Reinforcing Steel	Lb	5,500	.063	346.00
Bend Reinforcing	Lb	5,500	.0075	41.30
Place Reinforcing	Hr	44	1.05	46.20
Forms	BF	4,000	.09	360.00
Make up Forms	Hr	90	1.05	94.50
Erect and Remove Forms	Hr	135	1.05	142.00
Move Forms	Hr	30	.75	22.50
Mix and Place Concrete	Hr	200	.75	150.00
			Total	$3,455.00
			17% Overhead	586.00
				$4,041.00

The preceding unit prices were taken from references 9, 11, 12 and 13.

CONCLUSIONS

The costs of the prestressed bridge and the conventional bridge are for all practical purposes the same. This indicates that prestressed construction has certain inherent advantages, such that when it is integrated in a structure as a whole, it compares much more favorably than when individual elements are compared, as is shown in Part I.

There results a considerable saving in steel by using the prestressed design which, as brought out in the Introduction, is of ever increasing importance. This saving in steel is not achieved at the expense of using additional concrete.

Another factor which deserves consideration is the time required for construction. The prestressed beams were fabricated while the substructure was being built and were erected as soon as it was completed. The total construction time for the prestressed bridge was 7 days, which is less time than would be required to erect the conventional bridge.

Since the superstructures only were compared, it is possible that a more expensive substructure would be necessary

to carry the additional dead weight of the conventional bridge. If such was the case, the prestressed design would be even more favorable.

PART III

COMPARISON OF A HIGHWAY OVERPASS BRIDGE

It was next decided by the authors that the comparison should also include a large structure which was typical of those being constructed in considerable numbers at the present time. The super highway building programs which are being constantly increased in scope supplied a good example of such a structure. The Bridges, Grade Separations and Structures Section of the Construction Division, New York Department of Public Works, suggested a bridge which is part of the New York Thruway. This bridge is located east of Buffalo, New York, in Erie County.

This cost comparison is limited to the superstructure, assuming the same substructure will be used for both bridges. However, it is possible that a minor modification of the substructure may be necessary to carry an increase in super-structure dead weight.

The conventional bridge is now being constructed, under contract, by the Department. It is a four span, six lane overpass carrying Walden Avenue over the Thruway. The super-structure consists of wide flange sections with alpha spirals bonded into a conventional reinforced concrete structural

slab. The two center spans are 66', the two side spans 44', and the total width is 91' 4" out to out, including two 3' 8" sidewalks.

The prestressed bridge was designed for this site based on the same loading and the same overall dimensions. It consists of Tee beams on four simple spans replacing the wide flange sections, alpha spirals and the structural slab. The Tee sections are the obvious choice for a simple beam because they have a large compressive area of concrete. The thin web has sufficient area to carry the compressive prestressing force when the strand is tensioned, and is also large enough to carry the strand and provide sufficient cover to protect it from the weather. By placing the top flanges side by side the waterproofing and wearing course can be placed and poured without any in-place formwork except at the sides adjacent to the sidewalks.

The proposed construction procedure is first to prepare a flat working surface adjacent to the site, then to erect plywood forms while the substructure is being constructed. The beams would then be poured and when the concrete attains sufficient strength, the forms will be stripped and used for additional beam pourings while the curing process continues. When the beams have attained sufficient additional strength, the strand will be tensioned to the design tension by means

of a hydraulic jacking unit. After this tensioning they can be handled by a crane. In handling, two precautions must be followed: 1. They must be picked up at or very close to the ends with only two points of support, and 2. they must not be allowed to tip over to any appreciable extent while being supported at the ends. This can be very easily insured by using a lifting frame and slings with hooks at the ends.

The crane will pick up the beams and place them on the bents in the same manner as is done in erecting steel beams. When all the beams in one span are erected, the transverse strands will be threaded through the holes cast for them, in both the top and bottom of the transverse ribs, and then tensioned by means of the same hydraulic jacking unit and procedure. These ribs and strands will form transverse beams capable of resisting either positive or negative moment because of the dual strand position. These beams serve to tie the beams together rigidly and also distribute any concentrated load to the entire width of the bridge. The prestressed superstructure at this stage is equivalent to the conventional superstructure after the structural slab has been poured, allowed to cure, and the form work removed. The remaining work to complete the bridge would be done in almost exactly the same manner and sequence for both superstructures

As was previously stated, the authors sought to limit the comparison as much as possible in order to bring into sharp contrast the two designs and the cost of constructing each. This was aided by comparing only the main longitudinal structural system of the superstructure, assuming that the lengths of span and other limiting conditions of design were determined by considerations other than structural economy.

The authors recognize that there are many other solutions to the basic problem, such as eliminating the intermediate bents and using two spans of 110 feet each. This span length is not excessive for prestressed construction. This is because the stresses induced by flexure due to dead load alone are entirely eliminated at the time of prestressing so as to have no effect on the total load the beam can carry. This is not true of vertical shear or diagonal tension at the ends but this is no problem in prestressed beams (6). However, a comparison based on this solution or the many others possible could not be done due to time limitations. A study of the most economical combination of substructure and superstructure for any bridge is an involved and time consuming job, requiring complete and detailed information on foundation conditions, superstructure and substructure costs, which were not available to the authors.

PRESTRESSED BEAM DESIGN

The design of the prestressed beams was done using a Tee section. Since there is no direct solution for an irregular section, such as Mr. Uziel's for rectangular sections (5), it was a trial and error procedure using $\frac{P}{A} \pm \frac{MC}{I}$.

In section I of the design the loads were computed, the number of beams in the bridge assumed, and the bending moment due to live load and wearing course calculated.

In section II the required section moduli were calculated and a section assumed and checked. In section III the dead load moment was calculated. The prestressing force and eccentricity required to give the favorable stress condition desired were calculated in section IV. This permitted the calculation of the required strand size in section V and the selection of a strand from the Strand Physical Properties Table, page 24. With the size of section and strand determined, the stresses in the top and bottom fibers at the center line were checked in section VI under these two critical conditions: 1. when the strand is tensioned and the dead load of the beam alone is acting, and 2. when the beam is carrying the full dead and live design loads. The major principal tensile stress on the neutral axis at the support

was then calculated as a measure of diagonal tension in section VII. The transverse steel was designed in accordance with AASHO 3.3.2(c). The final calculation was made for the required area of the bearing plates at the ends of the strands in section IX.

DESIGN OF CENTER SPANS USING TEE BEAM SECTIONS

I. Loads

6 Lanes of H20-44

Span = 66'-0"; Lane width = 13'-4"

Sidewalk = 2'-6"; Mall = 4'-0"

From AASHO Specifications,

M_L per lane = 645,000 ft.lb. = 7,740,000 in.lb.

$$\text{Impact} = \frac{50}{L + 125} = \frac{50}{66 + 125} = .262$$

M_L + Impact = 1.262 x 7,740,000 = 9,750,000 in.lb.

Assume 42 sections per span, 3 sections under sidewalk, 39 sections under road

$$\text{Width of section} = \frac{91.33 \times 12}{42} = 26\tfrac{1}{8}"$$

$$M_L \text{ per section} = \frac{6 \times 9,750,000}{39} = 1,500,000 \text{ in.lb.}$$

Assume 4" wearing course

$$w_s = \frac{26.125 \times 4 \times 144}{144} = 104.5 \text{ ppf}$$

$$M_s = \frac{104.5(66)^2 \times 12}{8} = 683,000 \text{ in.lb.}$$

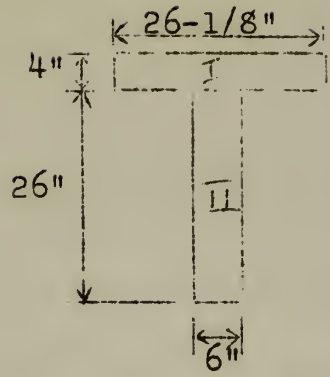
$M_T = M_L + M_s$ = 1,500,000 + 683,000 = 2,183,000 in.lb.

II. Section Modulus Required

f'_c = 5000 psi

f_c = 2000 psi

$$S = \frac{M}{f_c} = \frac{2,183,000}{2000} = 1092.5 \text{ in.}^3$$



Section	Size	A	y	Ay	Ay^2	I_o
I	4" x 26-1/8"	104.5	2	209	418	139.5
II	6" x 26"	156.0	17	2650	45,100	8,780.0
Total		260.5		2859	45,518	8,919.5

$$y_T = \frac{Ay}{A} = \frac{2859}{260.5} = 11"$$

$$y_B = 30 - 11 = 19"$$

$$I_x = I_o + Ay^2 = 8{,}919.5 + 45{,}518 = 54{,}437.5 \text{ in.}^4$$

$$I_{CG} = I_x - Ay_T^2 = 54{,}437.5 - 260.5(11)^2$$

$$I_{CG} = 54{,}437.5 - 31{,}500 = 22{,}937.5 \text{ in.}^4$$

$$S_T = \frac{I_{CG}}{y_T} = \frac{22{,}937.5}{11} = 2085 \text{ in.}^3$$

$$S_B = \frac{I_{CG}}{y_B} = \frac{22{,}937.5}{19} = 1205 \text{ in.}^3$$

2085 and 1205 $>$ 1092.5 $\therefore$ OK

III. Dead Load Moment

Assume 5 diaphrams in beam @ 11' cc

Diaphrams are tee sections of same cross section as beams.

$$w_{DL} = \frac{(26 \times 6 + 4 \times 26\frac{1}{8})}{144} \times 144 + \frac{5(6 \times 26)(26\frac{1}{8} - 6)}{66 \times 1728} \times 144$$

$$w_{DL} = 260.5 + 20.9 = 281.4 \text{ ppf}$$

$$M_{DL} = \frac{281.4(66)^2 \times 12}{8} = 1{,}840{,}000 \text{ in.lb.}$$

IV. Prestressing Force and Eccentricity

Critical conditions are stress in bottom fiber under dead and live loads and stress in top fiber after prestressing and prior to application of loads.

A. Stress in bottom fiber under dead and live load

$$\frac{P}{A} + \frac{Pe}{S_B} - \frac{M_{DL}}{S_B} - \frac{M_T}{S_B} = 0$$

$$\frac{P}{260.5} + \frac{Pe}{1205} - \frac{1{,}840{,}000}{1205} - \frac{2{,}185{,}000}{1205} = 0$$

B. Stress in top fiber

$$\frac{P}{A} - \frac{Pe}{S_T} + \frac{M_D}{S_T} = 0$$

$$\frac{P}{260.5} - \frac{Pe}{2085} + \frac{1{,}840{,}000}{2085} = 0$$

Solving for P,

A. $$\frac{P}{260} + \frac{Pe}{1205} - \frac{4{,}025{,}000}{1205} = 0$$

B. $$\frac{P}{260} - \frac{Pe}{2085} + \frac{1{,}840{,}000}{2085} = 0$$

$$P = 172{,}000$$

Substituting P in A.,

$$\frac{172{,}000}{260.5} + \frac{172{,}000e}{1205} - 3340 = 0$$

$$e = 18.8''$$

e = 18.5" is too large. It would not allow sufficient cover.

Assuming 2" cover and two strands place C.G. of steel 6" from bottom of beam.

$\therefore \quad e = 19 - 6 = 13"$

Revise P for e = 13" by substituting e = 13" in equation A.

$$\frac{P}{260.5} + \frac{13P}{1205} - 3340 = 0$$

$$4.61P + 13P = 4,020,000$$

$$P = \frac{4,020,000}{17.61} = 228,000 \text{ lb.}$$

V. Strand Size

Strand design stress = 105,000 psi

$$A_s = \frac{P}{105,000} = \frac{228,000}{105,000} = 2.17 \text{ in.}^2$$

Use 2 - $1\frac{3}{8}$" strands

$A_s = 2.24 \text{ in.}^2$

VI. Stress Check

A. Top and bottom fibers at center line due to dead load and initial prestress. Strands designed for 105,000 psi but initially prestressed to 125,000 psi to take into account loss of prestress due to plastic flow and creep.

$$P' = P \times \frac{125,000}{105,000} = 228,000 \times \frac{125,000}{105,000} = 272,000 \text{ lb.}$$

1. Stress in bottom fiber

$$f_b = \frac{P'}{A} + \frac{P'e}{S_b} - \frac{M_D}{S_b}$$

$$f_b = \frac{272{,}000}{260.5} + \frac{13 \times 272{,}000}{1205} - \frac{1{,}840{,}000}{1205}$$

$$f_b = 1045 + 2930 - 1530$$

$$f_b = 3975 - 1530 = 2445 \text{ psi (compression)}$$

$$f_c = 5000$$

$$f'_c = .45 \times 5000 = 2250 \text{ psi}$$

Stress in bottom fiber is 195 psi greater than f'_c but since creep plastic flow and any load will reduce it below f'_c it is considered satisfactory.

2. Stress in top fiber

$$f_t = \frac{P'}{A} - \frac{P'e}{S_T} + \frac{M_D}{S_T}$$

$$f_t = 1045 - \frac{272{,}000 \times 13}{2085} + \frac{1{,}840{,}000}{2085}$$

$$f_t = 1045 - 1700 + 885$$

$$f_t = 230 \text{ psi (compression)} \therefore \text{ OK}$$

B. Top and bottom fibers at center line due to dead and live load

1. Stress in bottom fiber

$$f_b = \frac{P}{A} + \frac{Pe}{S_b} - \frac{M_D}{S_b} - \frac{M_T}{S_b}$$

$$f_b = \frac{228{,}000}{260.5} + \frac{13 \times 228{,}000}{1205} - \frac{1{,}840{,}000}{1205} - \frac{2{,}188{,}0}{1205}$$

$$f_b = 875 + 2460 - 1525 - 1815$$

$$f_b \cong 0 \quad \therefore \quad OK$$

2. Stress in top fiber

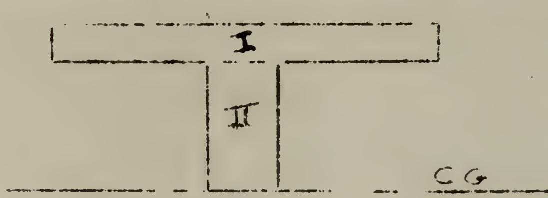
$$f_t = \frac{P}{A} - \frac{Pe}{S_t} + \frac{M_D}{S_t} + \frac{M_T}{S_t}$$

$$f_t = \frac{228,000}{260.5} - \frac{13 \times 228,000}{2085} + \frac{1,840,000}{2085} + \frac{2,188,0}{2085}$$

$$f_t = 875 - 1425 + 885 + 1055$$

$$f_t = 1390 \text{ psi (compression)} \quad \therefore \quad OK$$

VII. Diagonal Tension and Horizontal Shear on C.G. at Support



Section	A	y	Ay
4" x $26\frac{1}{8}$"	104.5	9	940.5
7" x 6"	42	3.5	147.0

Total = 1087.5

Horizontal Shear = $\frac{V}{It}$ x Ay

I = 22,937.5

t = 6"

Dead load shear = 281 x 66 = 18,500 lb.

Wearing Course shear = 104.5 x 66 = 6,900 lb.

Live load shear = 47,100 lb. per lane (AASHO)

Impact = .262

Impact shear = .262 x 47,100 = 12,350 lb. per lane

Total live load shear = $\frac{6(47100 + 12350)}{39}$ = 9140 lb/beam

$V = 9,140 + 18,500 + 6,900 = 34,540$ lb.

$\therefore \; s = \frac{34,540}{22,937.5 \times 6} \times 1087.5 = 273$ psi

Diagonal tension $f_{DT} = \frac{f'_t}{2} \pm \sqrt{s^2 + \frac{f'_t}{2}^2}$

$$f'_t = \frac{P}{A} = \frac{228,000}{260.5} = 875$$

$$f_{DT} = \frac{875}{2} - \sqrt{(273)^2 + \frac{875}{2}^2}$$

$$f_{DT} = 437.5 - \sqrt{266,000}$$

$$f_{DT} = 437.5 - 516$$

f_{DT} = 78.5 psi (tension)

Code allows $.03 \, f'_c$ without stirrups

$.03 \, f'_c = 150$ psi

$150 > 77.5 \; \therefore$ no stirrups

VIII. Transverse Steel AASHO 3.3.2(c)

$$\% = \frac{100}{\sqrt{S}} = \frac{100}{\sqrt{66}} = .13\%$$

$42 \times .13 \times 2.11 = 11.5$ in.^{2}

Area per diaphram = $\frac{11.5}{5}$ = 2.3 in.^{2}

Use 2 - $1\frac{7}{16}$" strands top and bottom

IX. Bearing Plate

P = 228,000 lbs

Area required = $\frac{P}{\text{Allowable bearing pressure}}$

Allowable bearing pressure = 2200 psi

$$\frac{228,000}{2200} = 103.8 \text{ in.}^2$$

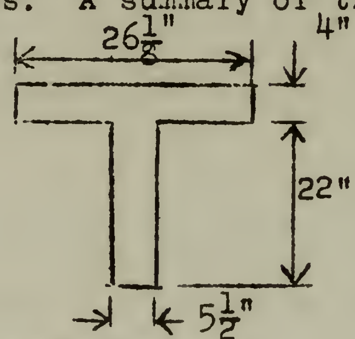
Area of 2 - 5" diameter holes = 39.2 in.^{2}

Gross area of plate = 103.8 + 39.2 = 143 in.^{2}

Use a plate 10" x 15".

DESIGN OF END SPANS USING TEE SECTIONS

This design was done in the same manner as for the center span; however, the design is not included here as the authors felt it would be superfluous. A summary of the results of this design follows:



1. Cross section found to be satisfactory:

   A = 225 in.^{2}

   Section modulus (bottom fiber) actual = 850 in.^{3}

   Section modulus (bottom fiber) required = 728 in.^{3}

   Section modulus (top fiber) actual = 1606 in.^{3}

2. Prestressing force:

   P = 120,100 lbs. Use one 1-7/16" strand

   e = 14.25"

3. Stresses at centerline:

   A. Under prestressing force and dead weight of beam alone

      Bottom fiber = + 2,078 psi compression

Top fiber = -166 psi tension

B. Under full dead and live design loads

Bottom fiber = +3 psi compression

Top fiber = +815 psi compression

4. Major principal tensile stress

f_t = 58.7 psi (tension)

Allowable tension = .03 f'_c = 150 psi

5. Bearing plate area = 81 in.^{2}

Use a plate 9" x 9".

<u>SUMMARY OF QUANTITIES</u>

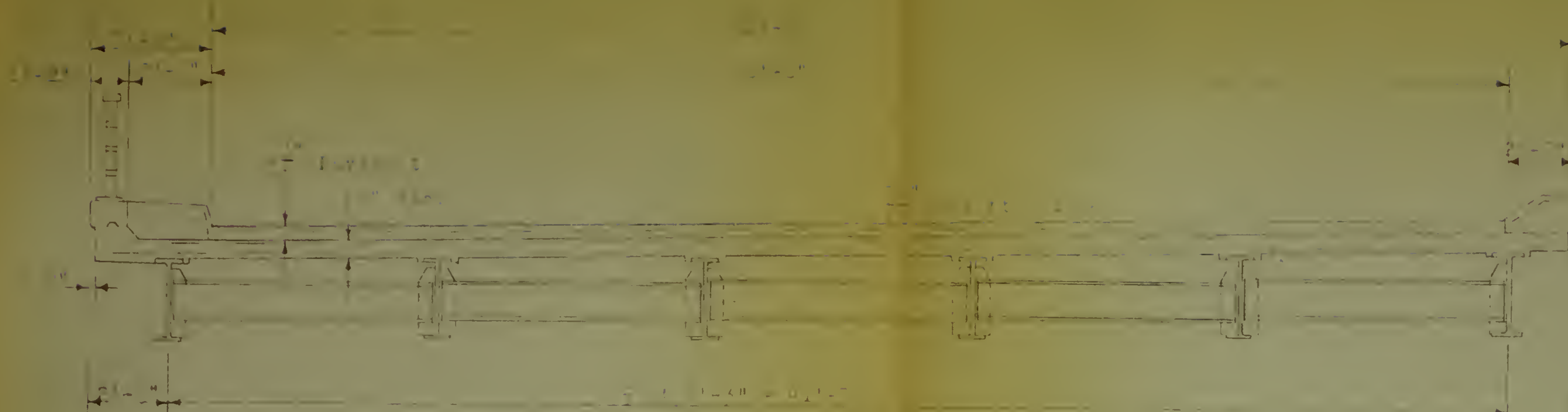
The elements which are compared in the two bridges are only those elements of the conventional bridge which were replaced by the prestressed beams in the prestressed bridge. All other items such as curbs, railings, waterproofing and wearing course were considered identical in both designs and thus not subject to comparison.

I. Prestressed Bridge - main longitudinal beams

A.	Concrete	726.6 cu yds
B.	Steel	115,850 lbs

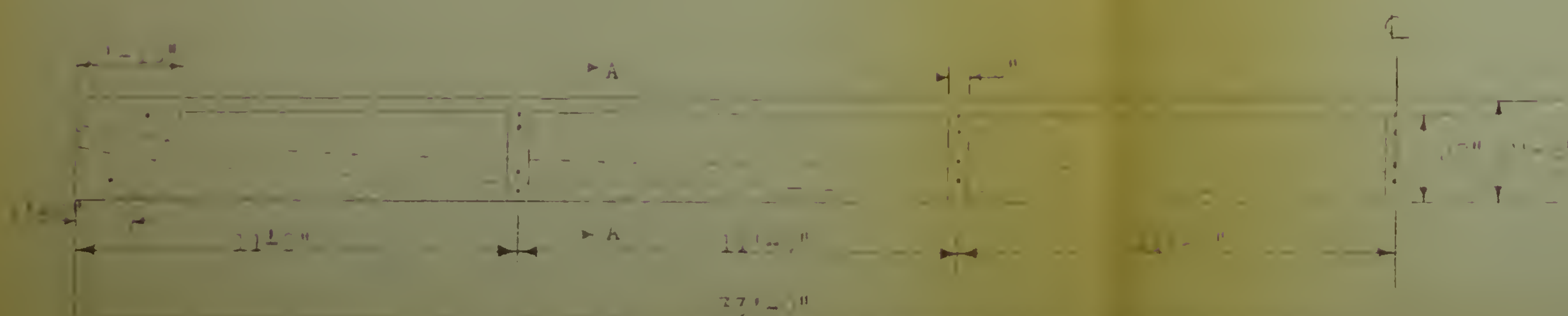
II. Conventional Bridge

A.	Concrete for 7" structural slab	530.2 cu yds	
	Cement for above concrete	825 Bbl	
B.	Slab reinforcing steel		142,082 lb
C.	Spiral steel		6,370 lb
D.	Structural steel		408,000 lb
		Total steel	556,452 lb

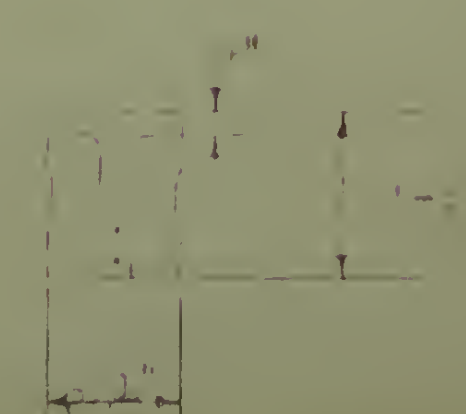


CONVENTIONAL BRIDGE - HALF SECTION AT CENTER

PRESTRESSED BRIDGE - HALF SECTION



SIDE ELEVATION - HALF SPAN VIEW



SECTION A-A

ESTIMATE OF PRESTRESSED BRIDGE COSTS

The cost of the prestressed beams was estimated by the same procedure as used in Part I. The concrete price was quoted by Buffalo Gravel Corporation of Buffalo, N. Y., for delivery to the site of the bridge. The strand prices were quoted by John A. Roebling's Sons, supplier. The erection cost was estimated on the basis of erecting an equivalent weight of steel. The hourly labor rates were quoted by the Buffalo office of the American Federation of Labor. All costs are those effective on March 1, 1951.

I. Fabrication

A. Center Spans

Plywood forms (each form used for 5 beam pourings), 84 beams, 528.75 SFCS/beam @ \$.0594/SFCS	=	\$2,632.00
Bearing assemblies (material and labor to fabricate), 168 pairs @ \$3.308/pr	=	556.00
Ready mix concrete, 84 beams, 5.475 cu yd/each = 460 cu yds @ \$10.40	=	4,780.00
Carpenter labor, 84 beams, 528.75 SFCS/each = 44,400 SFCS; $44{,}400 \text{ SFCS} \times \frac{9 \text{ hr}}{100 \text{ SFCS}} \times \frac{\$2.375}{\text{hr}}$	=	9,500.00

Common labor, 84 beams,

528.75 SFCS/each = 44,400 SFCS

$44,400 \text{ SFCS} \times \frac{4.5 \text{ hr}}{100 \text{ SFCS}} \times \$1.775$ = \$3,550.00

Structural iron worker labor,

168 strands @ 1/2 hr/strand

@ \$2.525/hr = 212.00

B. End Spans

Plywood forms (each form used for

5 beam pourings), 84 beams,

320 SFCS/beam @ \$.0594/SFCS = 1,597.00

Bearing assemblies (material and

labor to fabricate)

84 pairs @ \$3.308/pr = 278.00

Ready mix concrete, 84 beams,

3.175 cu yd/each @ \$10.40 = 2,775.00

Carpenter labor, 84 beams,

320 SFCS/each = 26,900 SFCS

$26,900 \text{ SFCS} \times \frac{9 \text{ hr}}{100 \text{ SFCS}} \times \frac{\$2.375}{\text{hr}}$ = 5,750.00

Common labor, 84 beams,

320 SFCS/each = 26,900 SFCS

$26,900 \text{ SFCS} \times \frac{4.5 \text{ hr}}{100 \text{ SFCS}} \times \frac{\$1.775}{\text{hr}}$ = 2,149.00

Structural iron worker labor,

84 beams, 84 strands

@ 1/2 hr/strand @ \$2.525/hr = 106.00

Total \$33,885.00

Total = $33,885.00

On concrete work 27% is allowed for overhead and profit and 2% for material waste. 0.29 x 33,885 = 9,810.00

Fabrication Total = $43,695.00

II. Prestressing Strands

Strand Cost = 48,360.00

On strands 10% is allowed for overhead and profit. 0.10 x 48,360 = 4,836.00

III. Erection - Labor, equipment rental, profit and overhead = 25,000.00

Grand Total = $121,891.00

COMPUTATION OF CONVENTIONAL BRIDGE COSTS

The quantities were taken from the design drawings of the bridge. The unit prices are taken from a compilation of contract prices on an identical bridge in the same locality which was contracted for on March 7, 1951.

I. Concrete for 7" Structural Slab

A. 530.2 cu yd @ $55.00/cu yd $29,200.00

B. Cement for above

825 Bbl @ $3.50/Bbl 2,887.00

II. Conventional Reinforcing Steel

142,082 lb @ $.13/lb 18,480.00

III.	Spiral Reinforcing Steel	
	6,370 lb @ $1.10/lb	$ 7,010.00
IV.	Structural Steel	
	408,000 lb @ $.16/lb	65,350.00
		$122,927.00

2% is allowed for material waste.

0.02 x 122,927 = 2,458.00

Grand Total = $125,385.00

CONCLUSIONS

The prestressed design shows an economy of $3,484.00. This is only 2.8% of the cost and, therefore, is not of great significance. The results, however, do show that prestressed construction compares favorably with combined steel and conventional reinforced concrete construction in a large structure.

The prestressed design required 196.4 cubic yards more concrete. It saved 220.3 tons of steel, the conventional bridge using 4.8 times as much steel as the prestressed.

Another factor in this comparison is the difference in construction procedures and the time they require. The prestressed beams can be fabricated at the same time the substructure is being built, and their erection can be started as soon as two adjacent bents are ready for the beams.

Thus it can be reasonably assumed that the prestressed bridge can be constructed in less time. This will convert some of the contractor's overhead expenses into profit, as he will be on the job a shorter period of time.

PART IV

FINAL CONCLUSIONS

A comparison of prestressed construction with conventional construction if done element by element does not give a true picture. This is shown by a comparison of the conclusions of Part I with those of Parts II and III. In Part I it was concluded that prestressed beams did not compare favorably in the range of spans 20 to 40 ft with applied loads up to 500 ppf. However, when these beams were incorporated in a structure, certain inherent advantages of prestressed construction, such as more efficient utilization of labor and materials, caused the comparison to change so as to show that prestressed construction was actually as economical as conventional construction when the structure as a whole was considered.

Prestressed construction results in a saving in steel of up to 60% in some cases over conventional reinforced beams. In the combined steel and concrete bridges compared in Parts II and III, prestressed construction replaced the main longitudinal steel sections and all of the conventional reinforcing steel with the small, very high strength prestressing strands. In Part III this resulted in a saving of 79.2% or 220.3 tons of steel. This is a matter of

considerable importance as brought out in the Introduction and should be given serious consideration. Prestressed design utilizes concrete more efficiently than does conventional; thus the considerable saving in steel is not accomplished by using additional concrete.

The trend of construction procedures using prestressed concrete is toward prefabrication as contrasted with in-place construction. This procedure permits fabrication to be done on the ground at a favorable site. This will considerably improve concrete's position in the competition with steel erection time.

It is the authors' opinion that prestressed concrete will become one of the major methods of construction in the future. This will be accomplished when design engineers and contractors become familiar with its many savings and advantages.

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